AERONAUTICAL ENGINEERING REVIEW

JULY 1948

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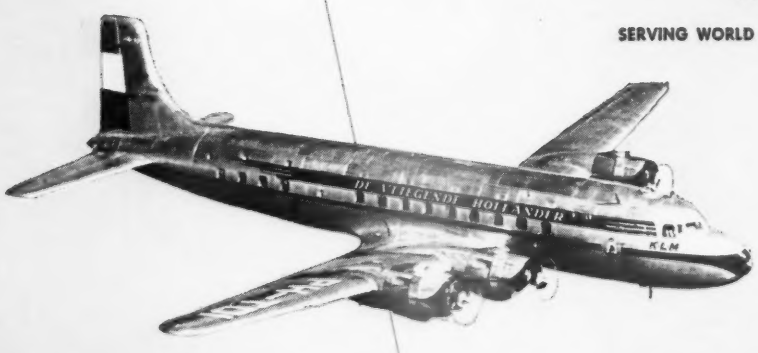

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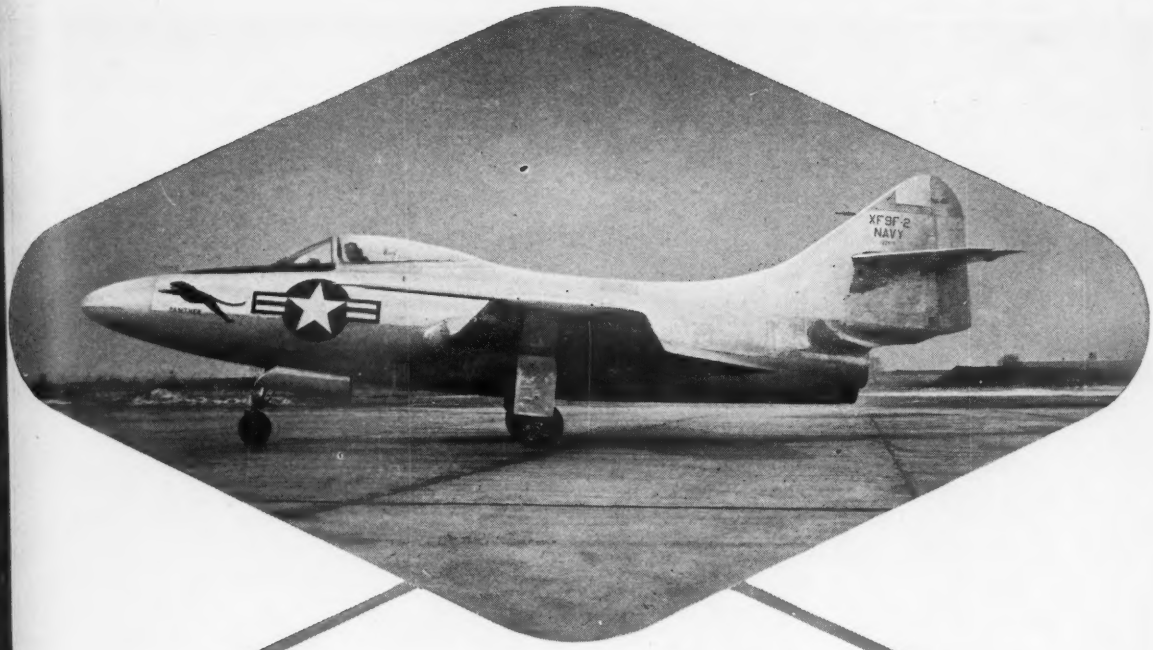

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(XF-9F)

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Contents

I.A.S. News 5
Editorial 19

Articles

Automatic Aircraft Control . . . . James L. Anast 20
Loss Prevention Programs in Civil Aviation . . . . . Jerome Lederer 25
The Application of Gas Turbines to Aircraft . . . . . Arthur N. Tifford 33
External Sound Levels of Aircraft . . . R. L. Field, T. M. Edwards, Pell Kangas, and G. L. Pigman 42
I.A.S. Briefs 50

Reviews

Aeronautical Reviews 55
Books 77

I.A.S. Preprints 52
Personnel Opportunities 87
Index to Advertisers 91

Published Monthly by the Institute of the Aeronautical Sciences, Inc.

OPERATION WATCHDO

These G-E technicians spend their working hours in a radio noise r at Schenectady "watchdogging" fully assembled aircraft ignition syst to make sure they will cause no radio interference. Today, as these haustive tests go on, production lines also keep moving at General E tric to answer the needs of commercial airlines and our peacetime forces. Ignition systems, jet engines, turbosuperchargers, armam systems, precision instruments and meters of all kinds are moving f the "backdoors" of our factories at a steady pace.

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GENERAL ELECTRI

I.A.S. News

A Record of People and Events of Interest to Institute Members

Symington To Speak at Summer Meeting Dinner

Air Force Secretary Will Address I.A.S. Members as Guest of Honor July 16; President Northrop To Present Bane, Chanute Awards. Atomic Energy To Be Subject of July 16 Luncheon Speaker, Comdr. J. T. Hayward of Navy's Sandia Base, N.M., Special Weapons Test Center.

SECRETARY OF THE AIR FORCE W. Stuart Symington will be the principal speaker and guest of honor at the Institute's Annual Summer Meeting Dinner, to be held on July 16 at the Hotel Ambassador in Los Angeles. The Secretary, who successfully spearheaded the campaign to obtain legislation for the 70-group Air Force this Spring, is expected to include some "off the cuff" remarks regarding the present outlook and expansion plans of the Air Force.

▸ **Two Awards at Dinner**—The Los Angeles Dinner last year was the occasion of the presentation of one award to a distinguished scientist. This year both The Thurman H. Bane Award and The Octave Chanute Award will be presented by President Jack Northrop.

As we go to press, the recipient of the Bane Award for 1948, Col. James M. Gillespie, U.S.A.F., has been selected for his part in the long-range automatic "push-button" flight from Wilmington, Ohio, to the Royal Air Force Station at Brize-Norton, Oxfordshire, England.

▸ **Atomic Energy Application**—At the July 16 Luncheon, Comdr. J. T. Hayward, U.S.N., Special Weapons Test Center, Sandia Base, N.M., will speak on "The Military Application of Atomic Energy." The Luncheon will be in the Ambassador's Spanish Room at 12:15 p.m.

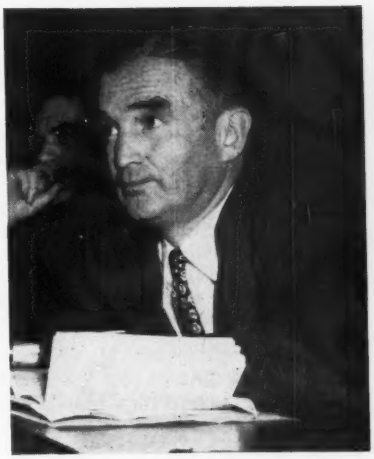
Tickets for the Dinner and Luncheon are $6.50 and $3.00 per plate, respectively, including tax and gratuities.

▸ **Final Program Outlined**—With the tour to the Pt. Mugu Naval Air Missile Test Center leading off the Annual Meeting on July 14, the Technical Sessions are scheduled to begin in the Ambassador Theater on July 15, with Registration at 8:00 a.m. At 9:00 a.m. the Morning Session on "Structures" will be opened by Chairman E. E. Sechler, Professor of Aeronautics, CalTech. Papers include:

- Application of Simultaneous Equation Machines to Aircraft Structure and Flutter Problems—P. A. Dennis, Chief, Engineering Labs, and D. G. Dill, Douglas Aircraft, El Segundo.
- The Shear Stress Concentration and Moment Reduction Factors for Reinforced Monocoque Cylinders Subjected to Concentrated Radial Loads—N. J. Hoff, V. L. Salerno, and B. A. Boley, Brooklyn Polytech.
- Principles of Structural Design for Minimum Weight—F. R. Shanley, Consulting Engineer and Lecturer, University of California (Los Angeles).

The Afternoon Session, "Aircraft Design," opening at 1:30 p.m., will be chairmanned by Frank Fink, Chief Engineer, Consolidated Vultee. Papers are:

- Application of Metallurgy to Aircraft Design—L. Schapiro, Metallurgical Engineer, Douglas Aircraft.



W. Stuart Symington.

- Servo-Systems for Aircraft—John R. Moore, Aerophysics Lab., North American Aviation, Inc.
- Recent NACA Research on High Length-Beam Ratio Hulls—A. W. Carter, Project Engineer, Hydrodynamics Div., Langley Memorial Aeronautical Laboratory.

On Thursday, July 15, the special Pilots Flight Symposium will be held at 8:00 p.m. under chairmanship of Col. C. A. Schoop, Special Representative of Hughes Aircraft, and Commanding Officer of 146th Fighter

National Meetings Calendar

July 14–16	Annual Summer Meeting, Los Angeles
December 17	Wright Brothers Lecture, Washington, D.C.
January 24–27	Seventeenth Annual Meeting, New York

For details see page 41.

Group, California National Guard. This will be a restricted meeting.

First on the Technical Session schedule for Friday, July 16, is the "Flight Propulsion" Session beginning at 9:00 a.m., with Chairman R. P. Kroon, Manager of Engineering, Aviation Gas Turbine Division, Westinghouse Electric, conducting. Papers include:

- Testing of Jet Engines Under Simulated Airspeed and Altitude Conditions—J. F. Manildi, Assistant Professor, University of California (Los Angeles), and Director of Research, G. M. Giannini Company, Inc.
- Jet Propulsion in Commercial Air Transportation—Robert E. Hage, Senior Group Engineer, Preliminary Design Section, Boeing.
- General Status of Rocket Work at GALCIT—JPL—Louis Dunn, CalTech.

"Naval Aircraft and Aerodynamic Research," the Afternoon Session, concludes the open meetings. Chairman is Capt. W. S. Diehl, U.S.N., Assistant for Research Liaison, Navy BuAer. Papers are:

- Flight and Tunnel Test Research on Boundary Layer Control—H. B. Dickinson, Flight Test Supervisor, Lockheed Aircraft.
- Design and Operation of a 12-In. Supersonic Tunnel—A. E. Puckett, Chief, Wind Tunnel Section, Jet Propulsion Lab., Guggenheim Aeronautical Laboratory, CalTech.
- Factors Influencing the Design of Carrier-Based Aircraft—Rear Adm. F. C. Lonnquest, Assistant Chief of Navy BuAer for Research & Development.
- Aerolastic Effects on Swept Wings—W. R. Sears, Director, Graduate School of Aeronautical Engineering, Cornell University.

Three I.A.S. Field Trips Highlight Activities in May

MEMBERS OF THE Institute of the Aeronautical Sciences and its New York and Los Angeles sections made three field trips in May: to La Guardia Airport on May 8 to view latest and most modern transports now in use or on order by the major air lines; to the U.S.S. "Coral Sea" on May 14 to witness carrier-based jet aircraft operations; and to the Navy submarine "Sawfish," also on May 14, to obtain an understanding of submarine technology and capabilities.

▶ **La Guardia Trip**—About 700 I.A.S. members and guests made a complete inspection tour of La Guardia Airport and a display of the world's most modern air transport aircraft through arrangements made by the New York Section with the Port of New York Authority and major air lines.

It was the first time that the foremost designs of commercial air liners ever were displayed in one exhibit. The planes shown included American Airlines' Convair 240; sleeper and day passenger versions of the Douglas DC-6 by American and United Air Lines; a Capital Airlines DC-4 Airfreighter; latest Eastern Air Lines Constellation; the Boeing C-97A transport, cargo version of the Stratocruiser operated by the Air Force; Martin 2-0-2 under Northwest Airlines' flag; and the Canadair Four, which incorporates basic features of the DC-6 design and is powered by Rolls-Royce Merlin 624 engines.

In addition, the Sikorsky S-52 helicopter ordered by United, and the McDonnell Phantom, piloted by Lt. Col. M. E. Carl, who holds the world's speed record of 650.6 m.p.h. on the Skystreak, were shown both on the ground and in the air. Colonel Carl, who flew up from Cherry Point, N.C., whistled over the field in the long-nosed Phantom in a flight demonstration that was caught by the television camera operator for the National Broadcasting Company program of the show.

The 40-passenger Canadair Four, one of Trans-Canada Air Lines' North Star transports, is the Dominion's first air liner entry in the international market. Having an overall length of 93 ft. 5 in. and span of 117 ft. 6 in., the C-4 has a maximum cruising speed of 333 m.p.h. at critical altitude of 26,000 ft. and a top speed of 345 m.p.h. Outwardly, except for the Merlins, it resembles the DC-6, although the fuselage is 80 in. shorter. Of particular interest was the special exhaust manifold, which is said to have not only drastically reduced the noise level but to have increased speed and performance by a clean-sided nacelle instead of the former multiexhaust stacks.

The tour, designed to cover all phases of operations of the airport, also included an inspection of American Airlines' operations, maintenance, and dispatching, as well as of air and ground traffic control, airport maintenance and operation, and crash rescue and fire-fighting equipment of La Guardia Field.

▶ **U.S.S. "Coral Sea" Visit**—The second East Coast field trip by I.A.S. New York Section members, on May 14, was marred by rain and low ceiling, which prevented the demonstration of jet plane operations. Nevertheless, the inspection of the mighty "Coral Sea" by the

Television Show at La Guardia Field: *With Bob Stanton, NBC announcer, holding the "mike" for Bill Littlewood, Vice-President of Engineering, American Airlines, the television program included in the La Guardia Field trip gets under way. Left to right: Bill Enyart, I.A.S. New York Section Chairman; Hervey Law, Port of New York Authority, operator of the airport; Jerry Lederer, President, Flight Safety Foundation; S. Paul Johnston, Director of the Institute; Capt. Dick Merrill, Eastern Air Lines Check Pilot; Sir Alan Cobham, British aviation pioneer; and Ben Horchler, Executive Vice-President of the Institute.*

220 Institute members and the trip up the Hudson to Pier 90 at 50th Street made deep impressions of the power and efficiency of the U.S. aircraft carrier.

Divided into ten groups of 22 each, members were conducted on a tour of the engineering department, the hangar deck, and the forecastle before lunching in the after messing compartment. Following lunch, a film, *The Fighting Lady*, was shown in No. 1 hangar bay, and four lectures on jet fighter and carrier operations were given.

Next, the groups rode No. 1 elevator to the flight deck to tour the deck and island structure. More than 110 ft. wide, the flight deck runs for 932 ft., equivalent to three football fields. There is more than enough space on the deck to hold all 125 aircraft of the carrier.

A discussion period with squadron commanders was later held in four ready rooms, and then the members were escorted to the gallery deck walkways to observe docking operations.

▸ **L.A. Section Visits Sub**—On the West Coast, 115 I.A.S. members of the Los Angeles Section inspected the U.S.S. "Sawfish." One of 203 virtually identical submarines turned out between Pearl Harbor and the end of the war, the "Sawfish" is 312 ft. in length and has a beam of 27 ft. and a draft of 67 ft. at periscope depth.

Members met at the U.S. Naval Officers Club on Terminal Island, San Pedro, at 6:30 p.m., where the entire party had dinner, and then walked the short distance to the submarine dock at 8 p.m.

Navy personnel, including the skipper, Commander Wright, explained all working parts and accommodations of the submarine from conning tower to keel.

Although problems in electronics, structures, and equipment are but remotely related to those in the aeronautical field, there is a direct similarity in space utilization and medical aspects.

Because so many requests had to be refused for the first trip, a second was scheduled and carried out on May 28.

Pan Am Buys Curtiss-Wright Electronic Flight Simulator

Pan American Airways has purchased the new, war-developed $200,000 Curtiss-Wright Dehmel Electronic Flight Simulator, a device that makes possible the scientific analysis and control of flight training and periodic instrument checks for pilots. It was conceived and designed by Dr. R. C. Dehmel of C-W Electronic Trainer Department.

The device, a complete replica of the Boeing Stratocruiser's flight deck, with all instruments and controls functioning precisely as in the actual aircraft, can train an entire crew together without leaving the ground.

Flight Training on The Ground: *An instructor supervising a simulated training flight in the Curtiss-Wright Dehmel Electronic Flight Simulator with a Pan American World Airways crew. Cockpit is an exact duplicate of the Boeing Stratocruiser. More than 40 problems in emergency or adverse conditions requiring corrective action by the flight crew can be introduced by the trainer, which reproduces realistically not only engine noises and instrument reactions to flight but the simulated sound of the wheels striking the runway as the plane "lands." Performance of the crew is traced by the "scriber" watched by the instructor, as flight engineer (center) reports to pilot on engine instrument readings. Board of switches and dials (right) produces indication of troubles on cockpit instruments.*

▸ **To Save Time and Money**—Pan American expects the trainer to save from $500–$600 per hour in direct operating costs and from 4 to 5 hours' airplane time in converting each of the air line's 70 crews to Stratocruiser equipment.

On top of the initial training economy, periodic instrument checks are expected to pay off even more in the end. Ordinarily, it could cost $3,500,000 to put a new plane into operation, according to Pan American.

Furthermore, the trainer can simulate emergencies—fire and crash landings—which cannot be done in actual flight-training operations, thereby obtaining a more thorough check on the pilot's reactions.

Andre A. Priester, Vice-President and Chief Engineer of Pan American and a Fellow of the Institute, noted that P.A.A. is the first air line to make this advanced instrument a regular part of the crew-training program. "The scientific analysis of crew techniques and habits made possible by Dr. Dehmel's device will result in increased crew proficiency and therefore in greater safety of revenue flight operations," he said.

N.A.C.A. "University Conference on Aerodynamics" Papers to Be Reprinted

The Durand Reprinting Committee, located at the California Institute of Technology, Pasadena, Calif., announced that permission has been received from the National Advisory Committee for Aeronautics to reprint the papers that were presented at the University Conference on Aerodynamics in June.

▸ **Reprint Program to Continue**—Sufficient information is not available at present to allow an announcement of the cost of this publication or the number of pages. It is expected that the reprint will be available concurrently or shortly following the Conference.

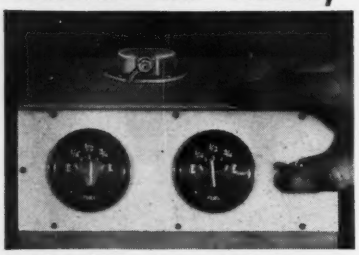
The Conference papers will initiate a program for the reprinting of the more important out-of-date N.A.C.A. publications. Persons interested in obtaining out of print N.A.C.A. reports are requested to inform the Durand Reprinting Committee regarding reports of prime interest.

▸ **Nonprofit Organization**—The Durand Reprinting Committee, a nonprofit body, was organized shortly before the war and is well known for

Silicone News

DC

Silicones Mean Stability



Silicone damping of gauge at right eliminates familiar fluttering of pointer shown in untreated automobile instrument at left.

Design frequently involves a compromise between simplicity of construction and the properties of available materials. New materials are interesting because they generally enable engineers to find more simple and therefore more efficient solutions to design problems. Damping is one of the problems that has been complicated by a lack of stability in fluids.

The instrument division of a large automotive parts manufacturer was not satisfied with the use of inertia wheels, air vanes, or magnetic damping to eliminate the fluttering of instrument pointers. Liquid damping had been considered, but all ordinary light oils or greases thinned excessively when hot or thickened and became useless when cold. More than two years ago, however, their engineers started testing some of our high viscosity silicone fluids.

Extensive road testing has proved that a fraction of a drop of our silicone fluid on the bearings performs better and is more economical than any of the more complicated mechanical damping devices. In tests conducted by aircraft manufacturers where operating conditions for instruments are even more severe, silicone fluid damping was found to be the only entirely successful method. Test performance was so completely satisfactory that the instrument division is now using our DC 200 Silicone Fluid to damp electrical instruments, speedometers, tachometers and gauges.

Among other unique and useful properties are a high degree of stability, a relatively constant viscosity over a very wide temperature range, and good lubricity between certain metal combinations. Our fluids are available in viscosities ranging from 0.65 to more than 250,000 centistokes. For more information phone our nearest branch office or write for catalog No. S 1-16.

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its reprinting program, which began with the six-volume set of *Aerodynamic Theory*, British R.T.P. Translations, and other publications, all of which are still in print.

Rentzel Named C.A.A. Head

Delos Wilson Rentzel, I.A.S. Member and former Chairman of the Board and President of Aeronautical Radio, Inc., was named Administrator of the Civil Aeronautics Authority by President Truman to succeed T. P. Wright, Honorary Fellow, and was approved by the Senate.

A veteran of 18 years' experience in aviation, he has been a licensed lightplane flier since 1936. He is a graduate of Texas A. & M. College.

In addition to being Chairman of Aeronautical Radio, a company owned by the air lines and which operates some 600 radio stations through which weather service is transmitted and flights are checked and controlled, Mr. Rentzel was a Director of Airborne Instruments Laboratory, Inc., and Chairman of the Radio Technical Commission for Aeronautics. He also served as an adviser with the Congressional Aviation Policy Board.

Gifts to the Institute Collections

An architect's airport model of a six-way field, with hangars, airway station, loading platforms, and model airplanes was received from John W. Wood. W. A. M. Burden added 100 periodicals to his previous generous gifts. Over 300 reports and periodicals were received from the Eclipse-Pioneer Division of Bendix Aviation Corporation, through the courtesy of Miss Mildred M. Baker. Dr. Alexander Klemin added books to his previous gifts. Periodicals were received from K. H. Weil, adding to his previous gifts. Howard A. Zeimer added eight buttons to those he previously gave.

A set of reports and summaries on compressible flow was received from The Graduate Division of Applied Mathematics of Brown University. The Cornell Aeronautical Laboratory, through the courtesy of Miss Elma T. Evans, added translations to those previously sent. The first lecture of a series in memory of Louis Blériot, given in France, was sent by F. R. Banks. Manuals and reports on aircraft and engines were received from the Douglas Aircraft Company, Inc.; Jacobs Aircraft Engine Company; Lockheed Aircraft Corporation; and the Chance-Vought Aircraft, Pratt & Whitney Aircraft, and Hamilton Standard Propellers divisions of the United Aircraft Corporation.

Among additional donors were the Boeing Airplane Company; Dr. Allan B. Crunden, Jr.; Massachusetts Institute of Technology, De-Icing Research Laboratory; National Council of Technical Schools; Texas Engineers Library; U.S. Bureau of the Census; Civil Aeronautics Board; and Navy Department, Bureau of Aeronautics.

Corporate Member News

• Employment boom...Reporting new employment increase of 2,278 since the start of its plant reactivation and expansion program in the 8-week period of March 21–May 21, **Boeing Airplane Company's Wichita Division** called for 1,000 additional qualified employees. The Wichita Plants expect personnel figure will reach between 6,000 and 7,000 by August 1.

• Cake is served...**Eastern Air Lines, Inc.,** which celebrated its 20th anniversary during a 4-day staff meeting in New York in May, was provided with a two-deck cake for the occasion.

• New wind-tunnel wrinkle is **North American Aviation's** nylon balloon to contain the dry air necessary to operate the supersonic wind tunnel now being erected. A chamber to house the 34-ft. balloon is under construction.

• First to break through $100,000,000 ceiling...**Pan American World Airways System** in 1947 became the first air line in the world to exceed $100,000,000 in annual passenger and freight revenues, Juan T. Trippe, President, announced in Pan Am's annual report. Gross commercial revenues were listed at $120,827,000 compared with $91,049,000, 1946.

• Operation and Maintenance Meeting was conducted early last month (June 4–5) by **Pratt & Whitney Aircraft Division,** United Aircraft Corporation, at Dallas, in Southwest Airmotive's hangar 21, Love Field. The 2-day clinic was designed to promote safer and more efficient engine operation. Similar meetings held in California and Minnesota proved so successful that the sessions were extended from 1 to 2 days' duration.

• Boom year in both national conventions and air travel to them is expected by **United Air Lines, Inc.,** in 1948 following a survey made by company's convention bureau. Conventions are being held in all major cities of the country and will continue in increasing numbers throughout the summer. GOP and Democratic conventions in Philadelphia head the list.

I.A.S. Newslines

▸ Associate Fellow **Andrew A. Andrake** has been named to Associate Partnership, Tranill of Burbank.

▸ New President of North American is I.A.S. Fellow **J. L. Atwood** who succeeds J. H. Kindelberger. Mr. Atwood has been with North American for 14 years and its first Vice-President since 1941.

▸ On South American tour...**Walter H. Beech,** President, Beech Aircraft Corporation, and member of I.A.S. Advisory Committee, is on an extended tour of South American cities. Flying in a new D-18S, he plans to be away about 30 days.

▸ A "flying wing" cargo plane designed for Arctic operations by Associate Fellow **Vincent Burnelli** was exhibited to 150 Aviation Writers Association members and aviation observers at Dorval Airport near Montreal. Plane carries 5 tons of cargo.

▸ Elected a Board member of the G. M. Giannini Company, Inc., **Charles H. Colvin,** Fellow and Member of I.A.S. Council, will direct broad policies of the company's instrument engineering and manufacturing activities.

▸ **William C. Gage,** Associate Fellow, was named Research Analyst, Research Department, Whiting Corporation.

▸ Bendix Aviation Corporation has appointed **Edward R. Godfrey,** Associate Fellow of the Institute, to post of Assistant to Executive Engineer.

▸ Production of 110,000,000 lbs. of air frames per year for 5 years would have little effect on the national economy by way of demands for steel and aluminum, **J. H. "Dutch" Kindelberger,** a Fellow, declared at a General Motors Club dinner in Los Angeles. "The air expansion program calls for only 30,525 tons of steel a year for construction of air frames, while the steel industry is turning out 90,000,000 tons a year," he said, adding that 3.4 hours of production of steel would meet requirements. Mr. Kindelberger is new Chairman of Board of North American Aviation, Inc., acting as Chief Executive Officer.

▸ Secretary of National Defense Forrestal named **Grover Loening** a Special Adviser on aviation matters. Most recent previous public assignment held by Mr. Loening, a Fellow, was that of Consultant to the President's Air Policy Commission.

▸ Institute of Transport (Great Britain) has elected **Sir Frederick Handley Page** to Honorary Membership. Sir Frederick, I.A.S. Honorary Fellow, was given the high honor for his services to the Institute.

▸ Fairchild Engine & Airplane Corporation's new President, **Lawrence B. Richardson,** an I.A.S. Fellow, has been elected a Vice-President of the Wings Club, New York City.

▸ Re-elected National Chairman of A.T.C...**D. Roy Shoults,** Associate Fellow, and Vice-President of Engineering, The Glenn L. Martin Company, was re elected National Chairman of the A.T.C. of the Aircraft Industries Association.

▸ Royal Aeronautical Society has announced its next-to-top award of the Silver Medal to **Igor I. Sikorsky,** I.A.S. Honorary Fellow, for his helicopter developments.

▸ **Earle Stewart,** an Associate Fellow, resigned from The Glenn L. Martin Company as Engineer to accept the same post at Fairchild Aircraft Division, Fairchild Engine & Airplane Corporation.

▸ On Canada-Bermuda inaugural flight, **Dr. Edward P. Warner,** President of ICAO, and I.A.S. Fellow, flew on Trans-Canada Air Lines' pressurized North Star for inspection trip with Dominion Government and international aviation representatives to Kindley Field.

▸ Stark realism...At Texas A. & M. College, where he has been given offices and tools for research, **Fred E. Weick,** a Fellow, will be concerned with perfecting the reliability of engines in small aircraft and with developing a simpler blind flying system, it is reported. Designer of the Ercoupe, engineer Weick does not believe the airplane ever will take the place of the car..."Who would want to take a plane to the corner drugstore?" he asks.

▸ Brown University has named **Dr. John R. Weske** Visiting Professor of Engineering, Engineering Division. Dr. Weske, an Associate Fellow, had been Consulting Aerodynamicist, Sverdrup & Parcel.

▸ **Harry Woodhead,** who is recovering from a breakdown in health, has been elected to the newly created post of Vice-Chairman of the Board of Consolidated Vultee Aircraft Corporation. Mr. Woodhead, an I.A.S. Member, resigned as President in order to accept the new position.

I.A.S. Sections

Baltimore Section

David P. Lamson, Jr., *Secretary*

Following a short business session opened by George N. Mangurian, Vice-Chairman, who presided in the absence of the Chairman, Capt. C. H. Schildhauer introduced the speaker of the evening, Ivan H. Driggs of the Navy's Bureau of Aeronautics.

▸ **Turbine Engine Performance**—Mr. Driggs' talk traced the development of turbojet and propeller turbine power plants by a description of a gas-turbine generator. By means of charts he showed the performance variations with compression ratios.

Mr. Driggs also illustrated by charts the effect of component efficiencies on generator performance, stating that generators are now working to 85 per cent efficiency but may go to 90 per cent, depending on aerodynamic and manufacturing limitations. Specific generator horsepower may increase from 40 to 120, he said, if the efficiency is increased from 0.80 to 0.90.

▸ **Fuel Consumption Comparison**—Turbojet and propeller turbines are efficient at very high airplane speeds. A comparison of specific fuel consumption was given as follows:

	Turbojet	Turboprop
Specific fuel consumption	0.6 lb. fuel per t.hp.hr.	0.45 lb. fuel per t.hp.hr.

Because of the weight difference in the two power plants, they must each be considered in the weight and performance requirements of the airplane. The turboprop is more efficient than the turbojet, but the weight feature is not so good.

Effect of heat exchangers at the tail end of a turboprop increases the efficiency of the engine at high speeds, Mr. Driggs said. This is ideal for long-range aircraft because of the lower specific fuel consumption, but again the weight penalty is considerable.

Dayton

E. W. Robischon, *Secretary*

The April 30 meeting, held in the Aeroproducts Division of General Motors at Vandalia, was turned over by Chairman A. A. Arnhym to F. E. Lehman, Manager of Sales & Services Department, who conducted the technical session following the buffet supper. Sixty-five members were present.

▸ **Turbine Prop Control**—A short film showing a P-82, equipped with Aeroproducts propellers, making a forced landing, to illustrate the ability of the

(*Continued on page 11*)

Meet Your Section Chairman

Albert A. Arnhym

Dayton Section

Chairman of the Dayton Section since its reactivation in the spring of 1947, Lt. Col. Albert A. Arnhym has been Chief of the Air Documents Division, Air Materiel Command, Wright Field, since January, 1947. He was commissioned a Colonel in the Air Force in 1946 and had served as Editor-in-Chief of the Air Documents Division and its predecessor, Air Documents Research Center, U.S.T.A.F., since its inception in London in the spring of 1945.

▶ **Educated in Europe**—Born in Plymouth, England, in 1906, Colonel Arnhym was educated at the University of Berlin and the University of Prague, receiving the degrees of B.A., B.S., and M.S., Aeronautical, Mechanical, and Electrical Engineering, and at the National Radio Institute, Washington, D.C., where he studied radio communication.

In 1931 he became Chief Television Engineer with Sparks-Withington Company, Jackson, Mich., where he was in charge of research and development. Subsequently, he held the following engineering posts:

- Chief Engineer and President, Arnhym Laboratories, Inc., Chicago, in charge of engineering of electronic, electrical, and optical devices for aircraft and allied applications, 1933–1938.
- Consulting Engineer (private) engaged in engineering and design of special electronic and electrical devices for aircraft applications, 1938–1939.
- Chief Engineer, Howard Ketcham, Inc., New York City, in charge of design of aircraft accessories, principally for commercial aircraft, 1939–1941.
- Vice-President and Chief Engineer, Airmax Corporation, San Diego, in which capacity he was engaged in accessory work for aircraft, particularly for heating, ventilating, and soundproofing military planes.
- Consulting Engineer (on military leave of absence), Solar Aircraft Company, San Diego, acting as consultant on development and manufacture of aircraft accessories, specifically heating, ventilating, and soundproofing of military planes, 1943 to date.

▶ **Holds Patents**—Colonel Arnhym, who invented the radio-light phone for use in military maneuvers back in 1936, holds numerous patents pertaining to aircraft accessories, electronic devices, aircraft heating, ventilating, and soundproofing. He has authored a textbook, *Comfortization of Aircraft*, and about 50 papers, articles, and talks on accessories and documentation.

An Associate Fellow of the Institute, he also is a member of the Society of Automotive Engineers and National Aeronautics Association and is a Founder Member of the Helicopter Association of Great Britain.

Wilbur Clifton Nelson

Detroit Section

Elected 1947–1948 Chairman of the I.A.S. Detroit Section in May of last year, Wilbur C. Nelson's predominant professional interest has been in the fields of aerodynamic research and instruction.

In the post of Professor of Aeronautical Engineering, University of Michigan, his teaching duties cover experimental aerodynamics, propellers, and aircraft design. At the same time Professor Nelson supervises work in the university's intermittent-flow supersonic wind tunnel at Willow Run, as well as in Navy's Bureau of Ordnance supersonic tunnel at Daingerfield, Tex.

▶ **Started at Lockheed**—Receiving his B.S.E. at the University of Michigan in 1935, Professor Nelson joined the engineering staff of Lockheed Aircraft where he worked in the field of performance, flight, and wind-tunnel test from 1935–1936. The next year he was appointed by the Civil Aeronautics Authority for airplane propeller analysis and test. He remained with the C.A.A. until 1939.

In the meantime, in 1937, he had earned his Masters degree in Engineering at Michigan and had married Pauline Elizabeth Woodward, two notable accomplishments for a man of 24 years. The Nelson family now includes three boys and a girl.

▶ **With Engineering Projects**—In 1939 Mr. Nelson was associated with Engineering Projects, Inc., a small development group, as Project Engineer working on a hydraulic, constant-speed propeller, which subsequently evolved into the General Motors Aeroproducts Division.

Since then, Professor Nelson's work has been divided between instruction and research, interlarded with some administration. He was appointed Engineer and Consultant at the Johns Hopkins Applied Physics Laboratory in the summer of 1945, on leave of absence from Iowa State College, where he headed the Department of Aeronautical Engineering, becoming intensely interested in supersonic aerodynamics. The following year he was named to his present post at Michigan. He continues his work, however, with the Johns Hopkins Laboratory.

Professor Nelson is the author of the paper, "Airplane Propeller Principles" (1944) and has contributed to scientific publications, including the Institute's JOURNAL OF THE AERONAUTICAL SCIENCES.

▶ **Licensed Pilot**—A licensed private pilot, Professor Nelson manages to get in flying time; both he and Mrs. Nelson enjoy cross-country flights combined with color photography.

In addition to being an Associate Fellow of the Institute, he is a member of the American Society for Engineering Education and the Engineering Society of Detroit. In 1946 he won the Naval Ordnance Development Award.

I.A.S. Sections

(*Continued from page 9*)

propellers to absorb high stresses without fracturing, preceded the presentation of the paper, "Controls for Gas Turbine Propellers," by R. C. Treseder, Chief Design Engineer.

Treseder's paper outlined the intricate problems of control from the standpoint of rapid response requirements, accuracy of control and feathering. Problems of controlling gas-turbine props were compared by means of graphs with those of reciprocating engines. Development of the necessary formula required to design properly the gas-turbine propeller controls also was shown.

▸ **Tour Plant**—Members were given an opportunity of seeing the production procedure on Aeroproducts propellers ranging in horsepower from 250 to 2,500; testing facilities including vibration testing and test stands; experimental development, including new propellers designed with a tubular spar structure and formed cover sheet blade; electrical propeller deicers and generators; and electrical actuators ranging from 1,000 to 30,000-lb. load.

Hagerstown Section

J. Anthony Pauli, *Secretary*

Speaker of the evening at the April 27 meeting, who was introduced by Chairman Roy Lessard, was Kenneth P. Bowen, Assistant General Manager of Fairchild Aircraft Division, Fairchild Engine & Airplane Corporation.

▸ **Fairchild Operation**—Subject of Mr. Bowen's paper was "Fairchild Operation." In his outline of the elements involved in aircraft manufacture, Bowen stated that following receipt of a bid inquiry pertaining to a particular plane or project, a priced proposal is prepared consisting of engineering drawings and data, manufacturing breakdown, sketches of major tooling, outline of policy to be followed in detailed tooling, processing flow chart, cost and time estimates for engineering, tooling, manufacturing, materials, and facilities in accordance with predetermined schedules.

The importance of accurate scheduling and forecasting requirements to provide for uniform utilization of personnel was illustrated by a work load chart. This chart primarily showed the distribution of man-hours by project, permitting the scheduling of manpower in order to overlap manufacturing cycles and avoid valleys.

After receipt of a contract, an internal work authorization is issued scheduling departmental responsibilities and establishing labor hour and/or money budgets within which departments concerned must remain in the accomplishment of their tasks. Functions of each department are broken down on charts, showing schedule dates of completion for all connected operations. The manufacturing chart reflects the production breakdown of the plane into individual items in the blocks, permitting accurate checks relative to the progress of each operation.

An advance bill-of-material survey is made for the purpose of preparing lists of material and equipment requirements in order to allow suppliers the longest possible flow time to meet schedules.

From data obtained by the Field Service Department, which continually makes checks and compiles reports on performance and features, good or bad, on Fairchild aircraft in service, corrective action is taken by MCR's and Field Service Kits.

Bowen pointed out that Inspection "squawk" charts are made for each department and for the entire operation. These reflect the number of items inspected which require corrective action.

▸ **'Producibility'**—The term "producibility" has been injected strongly into the industry by Air Force procuring agencies and, according to Mr. Bowen, is very broad in scope. Some of the pertinent phases of Fairchild's compliance with producibility requirements are typified by the company's concentrated efforts to effect standardization, simplification, and the merger of Production Engineering with Design Engineering.

To assure producibility of design, the Air Force requires complete manufacturing plans covering experimental and production contracts. The plans cover the entire cycle from development to volume production and provide the Air Force with a basis to evaluate the contractor's ability to produce the article in the desired quantity. This evaluation received equal consideration with performance characteristics.

Specific items requiring consideration during design stages to emerge with a producible article are accessibility, maximum production breakdown, maximum use of standard parts, consideration of fabrication and assembly problems, standard installations of GFP, capacity of equipment and facilities, and use of special processes and strategic materials.

New York Section

E. M. Lester, *Secretary*

On May 8, some 700 members and guests of the Section met at La Guardia Field for inspection of modern transport aircraft and air terminal operations, and, on the 14th, 195 members visited the aircraft carrier U.S.S. "Coral Sea." (Stories on pages 6 and 7.)

Philadelphia Section

John Rogers, *Secretary*

Election of the 1948–1949 officers took place at the April 29 meeting at which 170 members were present. In addition, Ivan H. Driggs, Director of Aviation Design of the Bureau of Aeronautics' Research Division, presented a paper on "The Design Application of Various Methods of Gas Turbine Propulsion in Modern Aircraft Including Helicopters."

▸ **New Officers**—Results of the election of officers were: Chairman, Commander Paul J. Burr; Vice-Chairman, Alfred L. Wolf; Secretary, J. Albert Roy; Treasurer, Dale Hamilton. Advisory Committee members are: Carl De Ganahl, Leon Douglas, Paul E. Hovgaard, Hugh J. Mulvey, N. Stephano, Francis G. Tatnall, Dr. Michael Watter, and H. Russell Young.

Mr. Driggs presented a discussion of the applicability of turbine power plants to meet problems of modern military aircraft. He outlined and discussed the various factors in the selection of the propeller turbine arrangement versus the turbojet power plant. He also freely discussed his personal views on the subject of propulsion methods for rotary wing aircraft.

San Francisco Section

Roy T. Nilsen, *Secretary*

A Symposium featured the April 1 meeting of the Section. Three speakers, all from United Air Lines, Inc., presented talks on the subject of "Long Range Overwater Operation."

▸ **Summary of Operations**—P. E. Reeder, Manager of Honolulu Division, gave a summary of U.A.L. long-range operations including the A.T.C. contract operation during the war. He also commented from the pilots' point of view on the various recently developed navigational and landing aids all of which, he believes, should be integrated to provide facilities for scheduled operations.

▸ **Power, Speed Selection Methods.**—H. B. Chin, Performance & Operation Engineer, reviewed the conventional method for selection of power and speed for long-range operation. Included in the discussion were speed and power limitations for schedule operation in some airplanes and suggested methods which would offer more flexibility from operation standpoint to improve schedule reliability.

▸ **Pressure Pattern Flying**—M. V. Cochran, Chief Navigator, gave a résumé of pressure pattern flying. He also explained the use of the Bellamy formula by which can be obtained a pressure line of position as well as a single heading track. According to Cochran

radar altimeter is a "must" item in order to detour low-pressure cells.

Wichita Section

Approximately 40 members and guests attended the May 11 dinner meeting at Drolls English Grill, with 20 additional persons attending the technical session.

During a short business meeting, Mel Snyder was elected Institute delegate to the Wichita Council of Technical Societies.

An entertaining travelogue, *Wheels Over India*, presented by Walt Burnham, preceded the main part of the evening's program: "The Design of a Goodyear Trophy Racer," by Prof. Kenneth Razak, University of Wichita.

▶ **Students Design Racer**—Prof. Razak stated that the university senior students had designed a racer as a part of the requirements in their advanced design class. A model of the plane was thoroughly tested in the university's wind tunnel in arriving at the final configuration.

A prone position for the pilot was considered at one stage of the design, but was abandoned in favor of the conventional sitting position in view of the racing committee's requirements on visibility.

An N.A.C.A. low-drag wing section was chosen and, although the maximum lift coefficient is low, no wing flaps are used in the design. A low-drag spring-steel landing gear with inner wheel and brake fairing proved exceptionally clean in tunnel tests, Professor Razak said. A fixed gear is required for all planes of this type.

Members of the senior design class of the university were present and took part in the discussion following Prof. Razak's talk.

Student Branches

Academy of Aeronautics

The April 28 meeting, presided over by John Korbuszewski, Chairman, featured a film, *Power by Wright*, which traced the development and production procedures of Wright aircraft engines.

Aeronautical Industries Technical Institute

This newly organized Branch held its May 5 meeting with Chairman Hillman Studley presiding.

Guest speaker was James L. Straight, Manager, I.A.S. Western Region, who spoke on "The Formation of a Student Branch." Mr. Straight, congratulating the faculty, members, and officers upon the organizing of their Branch, reminded them of the many benefits deriving from it.

Two films were shown: *Report on Jet Propulsion* and *The World Series of 1947*.

Cal-Aero Technical Institute

With 105 members present, the Branch held its April 15 meeting, Chairman Francis L. Wright presiding. A talk on "Practical Economics of Airplane Design" was given by J. B. Edwards, Project Engineer on DC-6, Douglas Aircraft Company, Inc.

Newsreel shots of the DC-6 were shown at the end of the talk.

New officers for the coming season are: Chairman, Robert J. Cameron; Vice-Chairman, John F. Fonda; and Secretary-Treasurer, Reino J. Manty.

Catholic University of America

At the April 4 meeting, presided over by Chairman Francis G. De Bettencourt, the 60 members present heard B. A. Lindner, Manager, Washington office, Fairchild Aircraft Division, Fairchild Engine & Airplane Corporation, on the subject of "Requirements for a Career in Engineering." In it Lindner, who has been associated with numerous aircraft firms and is a graduate of the Institute of Technology in Breslau, Germany, detailed means of obtaining an engineering position. One of the prerequisites suggested by the speaker was that the prospective engineer be able to place his thoughts on paper.

University of Colorado

Randall C. Maydew, Chairman of the Branch, opened the April 15 meeting and introduced F. J. Kroll, who introduced the speaker of the evening, Dr. Harold W. Sibert. Title of the talk was "Shock Waves and Compressible Flow Phenonenon." Slides of schlieren photos of shock waves illustrated the paper.

Following the speaker, election of new officers took place. Results were: Chairman, Robert M. Wood; Vice-Chairman, Charles H. Smukler; Secretary, Eleanor F. Lieberknecht; Treasurer, Maurice A. Brull.

University of Florida

A special meeting was called by the Branch at 5,000 ft. over Palm Beach May 4 in a DC-4 Eastern Air Lines to express appreciation to the air line and Florida Power & Light Company for arranging a field trip to their installations in Florida.

Maintenance and modifications necessary for maximum efficiency of aircraft and equipment were shown the students in an inspection of Eastern Air Lines' base at Miami International Airport.

The second day of the field trip was spent at the Power & Light Company's plants in Miami, Miami Beach, and the site of the new plant at Cutler, south of Miami.

Georgia School of Technology

At the April 21 meeting the Branch elected Edmund E. Novotny as the Outstanding Aeronautical Senior at Georgia Tech.

It was announced by Louis C. Setter that the Aeronautical Department's display at the Engineers Day Exhibit won third place. The Branch thanked

New West Coast Branch Opened: *Under guidance of James L. Straight, I.A.S. Manager of the Western Region, a Student Branch has been organized at Aeronautical Industries Technical Institute. Group shown includes (left to right): James L. Straight; H. Studley, Chairman; H. D. Ludwig, Secretary-Treasurer; and R. B. McIntyre, Vice-Chairman.*

Setter for his work in designing and constructing a vertical wind tunnel and several helicopter models. The models flew successfully in the vertical tunnel, making an interesting and informative display

A film, *Cavalcade of Aviation*, and Lt. B. P. Casteel's Gun Camera combat pictures taken from his P-47 during operations in Europe were shown. Casteel is a Branch member.

Chairman Novotny presided at the meeting.

Kansas University

Second place was awarded to the Branch's large exhibit at the University's Engineering Exhibit April 16 and 17.

Greatest crowd-gatherer was a Heinkel He 162 jet fighter, the engine of which was started every half-hour and allowed to run for several minutes. An Me 109 also drew much attention.

Plans are under way in the Branch for the next year's exhibit.

Louisiana State University

Election of officers at the April 15 meeting resulted in the following: Chairman, John P. Jones; Vice-Chairman, Charles A. Hansbrough; and Secretary-Treasurer, Ellis L. McDonald.

New York University

At the April 22 meeting, Chairman Irvin G. Richlin presiding, a paper "High Speed Transport Design," was given by Harold Gumbel of Republic Aviation Corporation.

New officers elected on April 20 are as follows: Honorary Chairman, Prof. F. K. Teichmann; Chairman, Nathan Kotlarchyk; Vice-Chairman, Lloyd B. Lyon; Secretary, Frederick Frankel; Treasurer, Lester Kravitz.

University of Notre Dame

An informative and nontechnical talk on the aeronautical student and his future was given by E. J. Bruhn, Head of the School of Aeronautics, Purdue University, at the April 22 meeting. Chairman Walter J. Marut presided.

University of Oklahoma

Plans were discussed for the aeronautical engineering exhibit to be held in the Engineer's Open House in May. Chairman Cecil E. Davies presided.

Oregon State College

With Chairman Ray McPhearson presiding, the April 8 meeting was held at which a film, *Airplane Structure*, was shown.

Florida Branch's Sky-High Meeting: *Some of the Florida University I.A.S. Branch members in Eastern Air Lines' DC-4, where they held a special meeting to express appreciation to Eastern Air Lines and Florida Power & Light Company for arranging a field trip to their installations in Miami and vicinity. Chairman T. B. Pasteur of the Branch is directly behind the stewardess.*

Parks College of Aeronautical Technology

"Opportunities in Aviation" was the subject of a talk by A. C. Baudek, Training Manager, McDonnell Aircraft Corporation, at the April 15 meeting. Chairman Richard A. Dean presided.

Baudek stated that opportunities in aviation were increasing rapidly as a result of the expansion program for the Air Force.

The Pennsylvania State College

An informal meeting and first annual banquet of the Branch were held May 5. Principal speaker was Dr. Bruce V. Moore, Head of Department of Psychology, who gave an interesting talk on hypnosis, which included a demonstration in which the entire audience was falling asleep.

Purdue University

A film of the 1947 Cleveland National Air Races, entitled *Pylon Dusters*, and furnished by Kendall Oil Company, was shown at the April 20 meeting. Chairman George Campbell presided.

Rensselaer Polytechnic Institute

Election of officers was held at the closing meeting of the spring semester May 6. Results were: Chairman, Roger Schaufele; Vice-Chairman, William Brower; Secretary-Treasurer, James A. Sterhardt; Assistant Secretary-Treasurer, Robert Russell. Faculty Adviser is Prof. A. J. Fairbanks.

The films were shown: *The Connie* and *The Magic Flying Carpet.*

Syracuse University

An informal discussion, led by Robert Wyckoff, was held at the May 5 meeting. Subject was the President's Air Policy Commission report.

At the close of the meeting, a film, *The Hamilton Standard Propeller*, was shown. Douglas Bramhall, Chairman, presided.

Tri-State College

With Vice-Chairman Rocco A. Laurito presiding at the April 14 meeting, a report on the barrel-type wing and V-tail projects was given—they are to be wind tunnel tested as soon as the tunnel is available.

The Vice-Chairman presented a plan for short, informative talks to be given by the members. It was also planned to hold a joint meeting with the Civil and Photographic Societies to hear a talk by Mr. Talbert Abrams of the Abrams Instrument Corporation.

Virginia Polytechnic Institute

At a business meeting held May 4 four representatives of the Branch were appointed to the Engineers Club. Appointees were: W. D. Knox, A. N. Cole, A. W. Robins, and R. F. Wallace.

The May 18 meeting was turned over to Dr. M. S. McCay, Professor of

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Physics, who spoke on *Atmospheric Electricity*.

Chairman Herbert C. McClanahan presided at the meetings.

West Virginia University

The April 27 meeting was devoted to work being done by committees on the Engineering Show to be held in conjunction with the Greater West Virginia Weekend.

Harold R. Shore, Chairman of the Link Trainer Display Committee, reported on progress made by his committee. William S. Van Gilder was added to this committee.

Robert S. Shaffer was appointed Chairman of the Instruments Display Committee. Other members are: Earl K. West, F. Robert Morrison, and Donald W. Bennett.

The operation of the smoke tunnel was displayed and explained by Harry L. Richardson, and Miss Joann Berry and Mr. Thomas were appointed to the committee.

Chairman Ralph C. Cokely of the Branch appointed an Engine Display Committee composed of the following members: Robert M. Carmichael and Robert H. Spangler.

The Models Display Committee members are William E. Lawson and James M. Cubbage.

News of Members

Rudolph C. Adler has joined Douglas Aircraft Company, Inc., as Designer. He was owner of R. C. Adler & Company and had been Chief Engineer, All American Aircraft Products, Inc.

Francis B. Alexander, former A.A.F. Major and Administrative Assistant, Westfield Flying Service, is now Assistant to the Manager, Woods Flying Service.

John E. Ayers, Sr., was named Engineer, Chase Aircraft Company, Inc. He had been Weight Control Group Engineer at the Ryan Aeronautical Company.

Louis E. Barnes resigned as a partner with Barnes & Hopkins to become Engineer with North American Aviation, Inc.

Alan A. Barrie is now Administrative Vice-President, Trans Pacific Airline, John Rogers Airport, Honolulu. He had been Operations Manager with California-Eastern Airways and is a former Colonel, A.A.F.

Lawrence R. Becerra has been named Design Engineer, Delanne Aircraft Corporation.

Henry Berman, former N.A.C.A. Mechanical Engineer at Langley Memorial Aeronautical Laboratory, is at Carnegie Institute of Technology as Cyclotron Design Engineer.

Henry W. Bollinger, now Engineering Designer, Lockheed Aircraft Corporation, formerly was Assistant Designer, McDonnell Aircraft Corporation.

Aleck C. Bond, Graduate Student of Georgia School of Technology, has been named Aeronautical Research Engineer, Langley Memorial Aeronautical Laboratory, N.A.C.A.

Charles E. Burns resigned as Sales Engineer, National Automotive Fibres, Inc., to become Engineer, Baumann Aircraft Company.

Harry A. Campbell, former Project Engineer, Menasco Manufacturing Company, is with Fletcher Aviation Corporation as Aerodynamics Engineer.

Jerry W. Cummings, former Professor of Aerodynamics at Aeronautical University, is Consultant to Research Department, Aerodynamics, Saab Aircraft Company, Sweden.

Warren H. Curry is Research Associate, University of Michigan, having resigned as Engineer from General Electric Company.

Frederick W. David, former Chief Designer of the Aircraft Division, Commonwealth Aircraft Corporation, Australia, has been appointed Officer in Charge of Applied Aerodynamics, Division of Aeronautics, Council for Scientific and Industrial Research.

Arthur F. Dickow is Champion Spark Plug Company representative in the State of Oregon. He had been with North American Aviation as Inspector.

Nadim Farrar is Design Engineer—Industrial Buildings, J. H. Davies (Consulting Engineers). He had been Design and Weights Engineer, Rohr Aircraft Corporation.

Ralph Friedman resigned as Engineering Designer, Republic Aviation, to become Engineer, Gassner Aircraft Engineering Company.

Marcel I. Gould, former Wing Group Leader, Engineering Design, Canadair Ltd., Canada, is now Stress Analyst and Design Engineer, Industrial Manufacturers, Inc.

Bell Engineers Promoted: *Appointment of Roy J. Sandstrom (left) as Executive Chief Engineer and John F. Strickler (right) as Assistant Executive Chief Engineer was announced by Lawrence D. Bell, President of Bell Aircraft Corporation. The promotion of the two engineers, both 36 years old, followed the resignation of Robert M. Stanley, Vice-President in Charge of Engineering.*

Joseph M. Gready has been named to the Engineer-Mechanical Assistance Section, Rayon Division, E. I. du Pont de Nemours & Company, Inc.

Haakon Greena resigned from Consolidated Vultee Aircraft as Design Checker to take the post of Aeronautical Engineer, Naval Air Station, U.S. Navy.

Edward F. Grimstad, now Superintendent, Engineering and Production, Bethany Industries, Inc., had been with Mid-Continent Airlines as Project Engineer, Aircraft Weight Control.

Edmund A. Guzewicz, former Development Engineer, Revere Corporation of America, has been appointed Project Engineer, Chandler Evans Company.

Clyde E. Heaton, U.S.N.R. Lieutenant, is Engineer, Aeronautical-Weights & Analytical Group, Naval Aircraft Factory, Philadelphia.

Jeremiah C. Hege, A.A.F. Captain, is Assistant Project Supervisor, The Johns Hopkins University, in the Applied Physics Laboratory.

Harold N. Hertenstein, a member of the Parks College of Aeronautical Technology faculty since September, 1945, has been appointed Director of the Aviation Maintenance Engineering Department.

Henry F. Jordan, Jr., has been named Assistant Chief Engineer, Cleveland Aero Products, Inc. He had been Process & Specifications Engineer with The Cleveland Pneumatic Tool Company.

Dragoljub K. Jovanovich, former Consultant, Helicopter Company, has been elected President of the Helicopter Engineering Research Corporation.

Mark B. Komorn is Technical Manager, Yula Heaters, Inc. He had been with Republic Aviation Corporation.

Haig Kurkjian, former Piasecki Helicopter Corporation Flight Test Engineer, resigned to become Professor of Helicopter Theory and Design, Quaker City School of Aeronautics.

Charles H. Lauritsen, Navy Ensign, is with North American Aviation, Inc., as Engineer (Aero Physics).

Yuan C. Lee is Instructor of Aircraft Structures and Aerodynamics Research Associate, University of Southern California. He had been Structures Engineer at Consolidated Vultee Aircraft Corporation.

Miss Loren Lewis, former Analytical Engineer with Platt-LePage Aircraft Company, is now Project Engineer, Power Generators Ltd.

Lionel London is Structural Designer, Sessions Engineering Company. He resigned from Holabird & Root where he was Structural Designer.

Richard J. Markey has been named Factory Manager, Penmarva Electric Manufacturing Company.

Carl J. Martin, former Flight Analyst—Aeronautical Engineer with C.A.A., returned to BuAer of Navy Department as Engineer.

Merlin L. Millett, Jr., Iowa State College Graduate Student, has been appointed Aerodynamicist at Douglas Aircraft Com-

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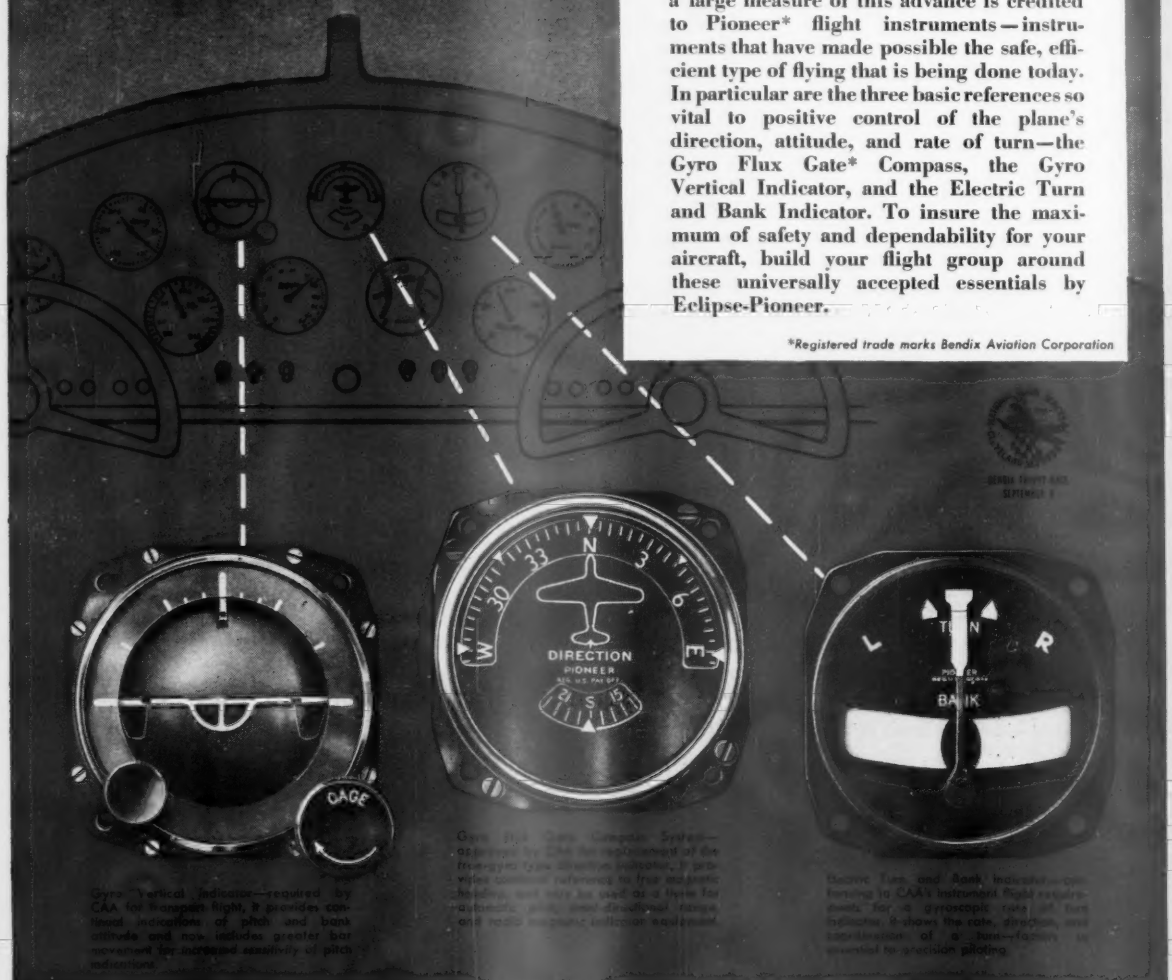

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pany, Inc. He received his Masters degree from Iowa State.

Anthony P. Monaco, formerly with Andover-Kent Aviation Corporation, is owner of Monaco Engineering Company.

Richard Dana Moog has joined the faculty of University of Michigan as Instructor. He had been a Computer with Geophysical Service, Inc.

Eugene C. Muggleton is in the Process Engineering Department, Reliance Electric & Engineering Company.

Warren E. Oesterling, former engineering trainee at Cooper-Bessemer Corporation, has been promoted to Assistant to the Plant Engineer of the company.

Arthur M. Ogness is Assistant Professor of Aeronautical Engineering, University of Illinois. He had been Stress Analyst A of Douglas Aircraft Company, Inc.

Paul E. Pedersen is Instructor in Stress Analysis—Design & Lofting, Structures Department, Aeronautical University of Chicago.

John O. Powers resigned from Electrical Equipment Corporation to become Assistant Project Engineer, David Taylor Model Basin, Navy Department.

John P. M. Reid, former student at the Royal College of Aeronautics, England, is Engineering Liaison Pilot, Rolls-Royce Ltd.

Lewis A. Rodert, winner of 1946 Collier Trophy for anti-icing device (AERONAUTICAL ENGINEERING REVIEW, January, 1948) who is Flight Test Division Chief at the N.A.C.A. Flight Propulsion Research Laboratory at Cleveland, is heading up new N.A.C.A. subcommittee appointed to study means of combatting fire hazard in aircraft.

Theodore Romans resigned from Republic Aviation Corporation as Landing Gear Group Leader to become Staff Designer, Chance Vought Aircraft Division, United Aircraft Corporation.

Jack E. Rothman has been named Aeronautical Engineer, Research and Development, United Air Lines, Inc. He had been Assistant to Superintendent of Engine Development.

Arthur B. Schultz, former Chief Engineer with All American Aviation, is now Executive Engineer, Tucker Corporation.

Lawrence C. Sentker, Research Analyst with Hughes Aircraft, resigned and was appointed Aeronautical Engineer, C.A.A.

John F. Shea resigned as Design Engineer, Imagineering Associates, Inc., to become Engineer—Industrial Design Associates.

Thomas M. Shelton resigned as Vice-President in Charge of Engineering, Aero Crafts Corporation, to become Chief Engineer, Budson Company.

Ned E. Shott who had been Assistant to Publisher, *New York Times*, is Executive Vice-President, Air Cargo Transport Company.

Sali Thomas Simon, former Lieutenant Commander with BuAer, Navy, has been named Hearing Examiner, C.A.A.

Miss Betty Mae Strasser is a Computer at Bell Aircraft Corporation.

Rear Admiral John H. Towers.

Clinton S. Strong, who was Assistant Project Engineer, Sikorsky Aircraft Division, United Aircraft Corporation, was elected President of Technical Design & Development Company.

Marvin R. Sward has been named Engineer-Draftsman at North American Aviation, Inc.

Admiral John H. Towers, U.S.N. (Ret.), has been elected Assistant Vice-President of Pan American World Airways System.

Ralph B. Trueblood is at M.I.T. as Research Engineer. He had been with Fairchild Engine & Airplane Corporation, Personal Planes Division, as Structures Engineer.

Robert L. Turner, Jr., is a Graduate Student and Research Assistant at University of Texas.

John C. Vogtle, former Stress Engineer with E. G. Budd Manufacturing Company, is now Senior Stress Engineer, Piasecki Helicopter Corporation.

Ernest E. Walker, an aviation writer, has been named Airport Planning Consultant, Department of Commerce, C.A.A.

Robert G. Wilson was named Supervisor of Preliminary Design, Aerophysics Department, North American Aviation, Inc. He had been with Consolidated Vultee Aircraft Corporation as Stress Analyst.

Boleslaw Paul Wisnicki resigned as Aeronautical Engineer with Brisbane Aviation Co. Ltd., Canada, to become Assistant Professor, University of British Columbia.

Robert P. Wold, U.S.N.R. Lieutenant (j.g.), is a Partner and General Manager, The Wolmac Company.

Charles M. Zimney, Purdue University graduate and former Aeronautical Engineer with N.A.C.A., is Assistant Professor of Aeronautical Engineering, University of Minnesota.

Members Elected

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the REVIEW.

Elected to MEMBER Grade

Carter, Harry Akers, M.S. in Ae.E., Flight Test Project Engineer, Boeing Aircraft Co.

Dougherty, James Edward, Jr., B.C.E., Sr. Aero. Engineer, Chief, Materials Unit, Airframe & Equipment Engineering Div., Dept. of Commerce, C.A.A.

Echeverria, Charles Manuel, Jr., B.S. in M.E., Sr. Test Engineer, Sikorsky Aircraft Div., United Aircraft Corp.

Ellerbrock, Herman Henry, Jr., B.E., Chief, Turbine Cooling Branch, Flight Propulsion Research Lab., N.A.C.A.

Frank, Merle Jack, B.S. in M.E., Chief of Laboratories, Fairchild Aircraft Div., Fairchild Engine & Airplane Corp.

Hoffman, Frank Charles, Jr., Test Pilot, The Glenn L. Martin Co.

Johnson, Donald S., B.S. in M.E., Research Asst., Dept. of Mechanical Engineering, Lehigh University.

Larsen, Harold C., M.S. in Ae.E., Prof. of Aerodynamics & Aircraft Design, Air Force Institute of Technology.

Saksena, Gajraj Bahadur, M.Sc., Asst. Chief Stressman, Messrs. de Havilland Propellers, Ltd. (England).

Sauers, William F., M.S., Secy. & Exec. Engineer, Chase Aircraft Co., Inc.

Soenke, John E., B.S., Business Mgr.—Commercial Airplanes, The Glenn L. Martin Co.

Stephens, Thurman Warr, B.S., Engineering Designer—Guided Missiles Project, Douglas Aircraft Co., Inc.

Tvedt, Joseph Arnold, Ae.E., Lt. Comdr., Head, Airframe Section, Maintenance Div., Bureau of Aeronautics, U.S. Navy.

Twomey, Irving, A.B., Aero Research Engineer, United Aircraft Corp.

Vazaca, Christopher Stephen, M.Sc. (Eng.), Asst., The National Institute of Technological Researches (Bucharest, Roumania).

Yeh, Hsuan, M.S., Instructor, Mechanical Engineering Dept., M.I.T.

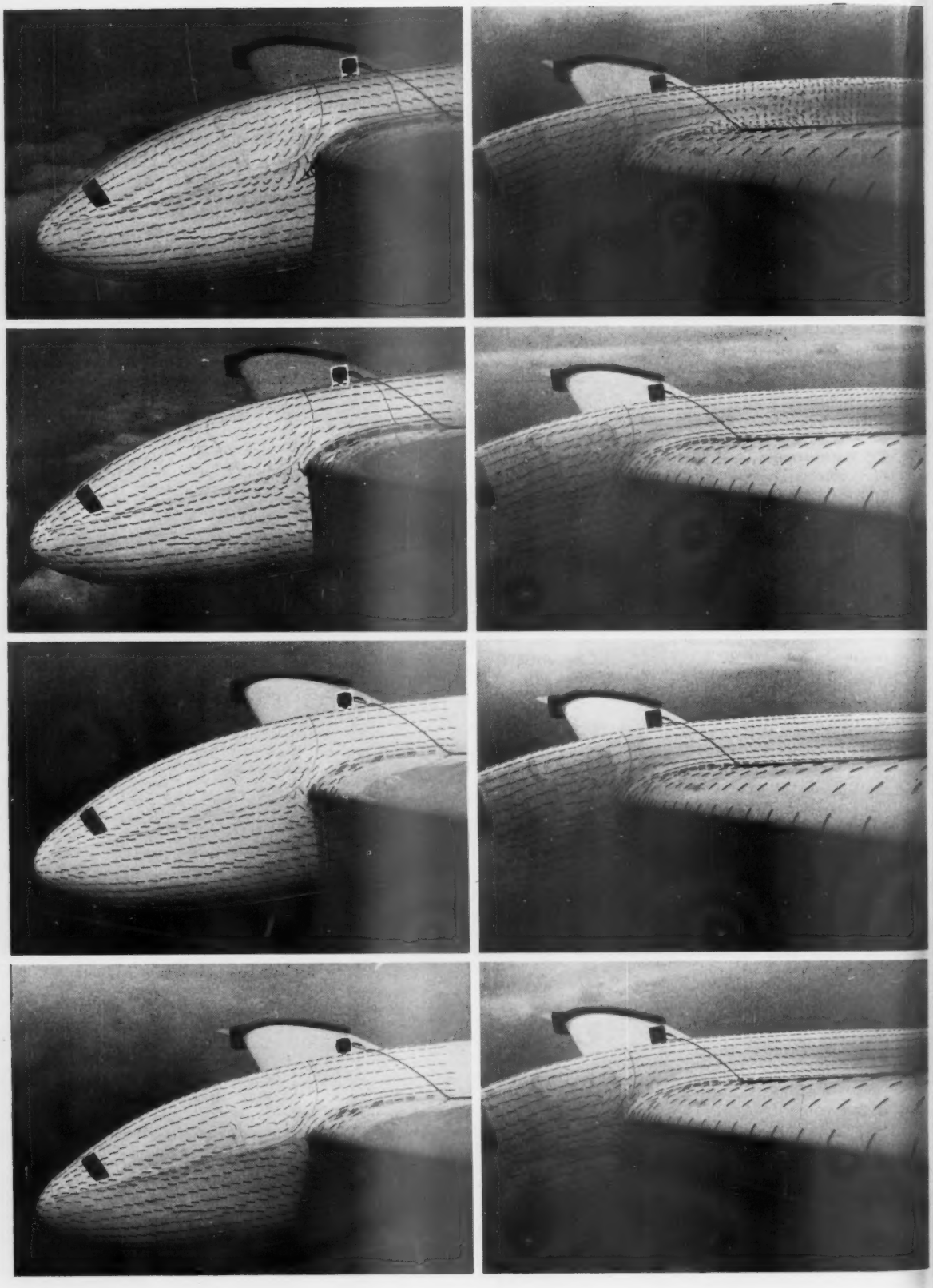
Transferred to MEMBER Grade

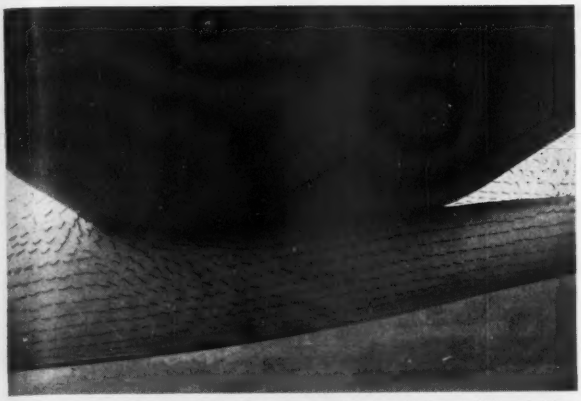
Dankenbring, Henry Dieter, M.E., Layout Designer, Pilotless Aircraft Section, The Glenn L. Martin Co.

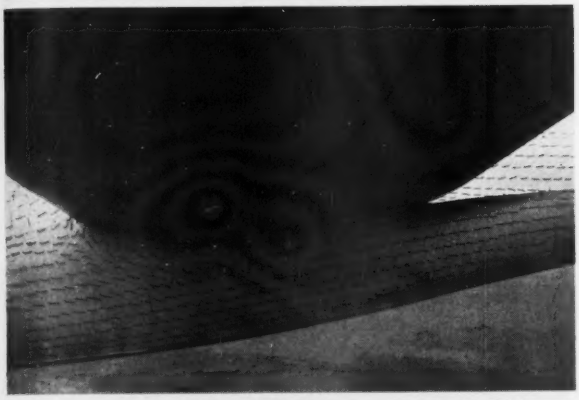
Davenport, Edward Lounsbury, Jr., B.Ae.E., Project Engineer P-2, General Purpose Wind Tunnel, David W. Taylor Model Basin, Navy Dept.

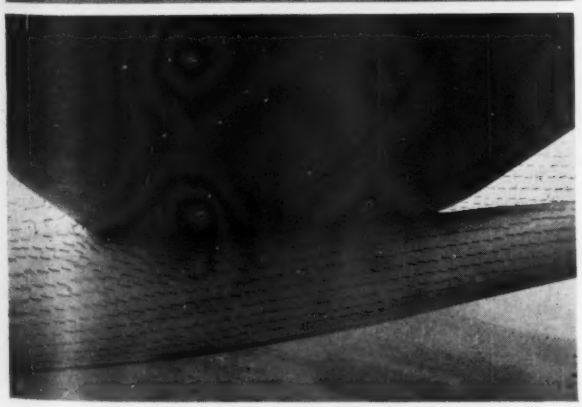
Graffy, Richard, M.S. in Ae.E., Lt., Bureau of Aeronautics General Representative, U.S. Navy (Wright Field).

(Continued on page 84)









Editorial

Silent Wings for Research

Motorless flying is not only one of the finest sports in the world but may also be a valuable research tool for the aerodynamicist, the structural designer, and the meteorologist. The use the Germans made of their prewar gliding and soaring is well known to all of us. A good example of the thoroughness of German work is illustrated on these pages. We have not looked upon such activities as seriously as did the Nazis—our virtually unlimited research facilities made it unnecessary. But there is much that can be learned from free flight in sailplanes, and aeronautical scientists may do well to keep a sympathetic and appreciative eye on the work of the soaring enthusiasts in this country.

Some years ago the Institute undertook to collaborate with the Soaring Society of America on technical matters through joint meetings and exchange of papers, but the effort was cut short by the onset of war. The time now appears appropriate to resume that collaboration, and the I.A.S. and the S.S.A. have held their first joint meeting since the war. This took the form of a symposium on the Ultimate Performance Possibilities of the Sailplane staged in the Warren Eaton Memorial Building on Harris Hill at Elmira (N.Y.) during the Fifteenth Annual Soaring Meet. Our Panel of Experts let their collective imagination roam into the future, and the ensuing discussion was well worth the time of those who participated and those who listened. A full report of the discussion will appear in a later issue of the REVIEW.

Here is another example of profitable cooperation among technical societies for the advancement of the aeronautical sciences in America.

S. P. J.

A beautiful example of German flight research on the "Reiher" Sailplane. The pictures in the horizontal rows were taken simultaneously at flight speeds of 40, 60, 78 and 100 km. per hour, respectively (from top to bottom of page).

Photos Courtesy Aerophysics Institute, Inc.

Automatic Aircraft Control

JAMES L. ANAST*

All-Weather Flying Division, Air Materiel Command

Introduction

The complexity of control equipment with which a pilot is confronted in today's aircraft has led naturally to its simplification, because of a human pilot's growing inability to cope efficiently with the multiplicity of functions required in the operation of aircraft under all weather conditions.

In order to evaluate the system requirements of automatic aircraft control, the All-Weather Flying Division of the Air Materiel Command has designed and assembled a prototype "Automatic Flight Controller" that receives a flight plan and performs the aircraft control functions to accomplish a completely automatic flight in an elementary form.

The integration of this controller development with the philosophy of scheduled ground track operation, reliable automatic landing, and the necessary increase in reliability required in military and commercial applications is progressing concurrently with operational demands and the development of basic flight sensing equipment that has been determined as necessary by actual experimentation. This development is a result of a concerted action within the Air Materiel Command, coordinated with such agencies and committees that are interested in the operation of aircraft under all weather conditions.

It is probably more usual to present a résumé of completed research or development, therefore it must be stated that the work resulting in the "Automatic Flight Controller" is a skeletal fundament to be elaborated upon, modified, and essayed. The accomplishment, however, of successful all-weather flying must be implemented by such a program of progressive evaluation. In this manner, the theoretical concepts of all-weather aircraft operation, as proposed, can be refined into realities by actual experimental selection.

Automatic Flight Controller

The design of the prototype Automatic Flight Controller resolved itself primarily to the investigation of the adaptability of equipment, such as automatic pilots and automatic radio compasses, to automatic flight control and the development of ancillary electromechanical systems to reproduce the action of a human pilot in receiving flight information and the attendant control that he exercises. The equipment is integrated into a system that allows preselection of flight parameters and automatic sequential control of the aircraft to produce the flight that is preselected.

The schedule of the flight is determined by the Master Sequence Selector. This is essentially a multichannel, multipole electrical switch that advances in position when its energizing circuit is actuated. It completes a number of electrical circuits and holds them closed until an actuation is received. Thus, control of the automatic pilot and other ancillary components is applied sequentially as a function of the position of the Master Sequence Selector. The flight schedule progresses automatically by the use of sensory instruments that actuate the Master Sequence Selector at the end of each phase of the flight.

The basic component of the Automatic Flight Controller is its Sperry E-4 Automatic Pilot. The automatic pilot consists essentially of gyroscopic units and amplifying or servo devices that transform low-power signals derived from the gyroscopes to levels that can operate motors moving the aircraft control surfaces.

The automatic pilot provides a three-axis attitude reference, flux valve slaving of the directional gyroscope, electrically actuated rate-displacement servo control of the control surfaces, automatic trim-tab operation, barometric altitude control, automatic coordination of turns and coupling between the A.A.F. Instrument Low Approach System and the automatic pilot.

In addition to the automatic pilot, various devices are used in the production of automatic flight in order to translate basic flight information into actuating and control signals. In the Automatic Flight Controller, signals are introduced in the attitude circuits of the automatic pilot, by the error, as read by the flight instruments, from the preselected flight plan.

Magnetic Heading Selector

This is an electromechanical system operated from the flux valve of the automatic pilot to turn the aircraft on to an arbitrarily selected heading. It is essentially a selsyn system that feeds a voltage sensibly proportional to the error in aircraft heading from the selected reference to the turn control amplifier of the automatic pilot.

Radio Compass Controller

This is an electronic system that automatically "homes" the aircraft to a preselected radio station. The voltage from a zero-locked selsyn coupled to the Automatic Radio Compass transmitter selsyn is fed

Presented at the Air Transport Session, Sixteenth Annual Meeting, I.A.S., New York, January 26–29, 1948.

* Chief, Automatic Flight Branch.

through an integrator amplifier to the turn control amplifier of the automatic pilot. Integration is required in automatic homing to eliminate the effect of transient radio signals that are present under conditions of precipitation static. This control is used also for orbitting the aircraft in the "let down" sequence of the automatic flight.

Automatic Engine Control System

In order to vary the engine speed and power during the automatic flight, an automatic engine control system is used which provides power as a function of the input voltage. The basic equipment of this system is the Eclipse-Pioneer Single-Lever Control System. It provides automatic scheduling of the engine speed when the single lever that controls the manifold pressure of a multiengined aircraft is manipulated. An electromechanical coupling system is used to position the single lever from the preselected voltages that are applied sequentially through the Master Sequence Selector. To facilitate rapid pilot override in the event of malfunction, single dial control of all engines is afforded the pilot. The dial and selector is on the steering column where in an automobile the horn button is located.

Pitch Attitude Selector

To control the pitch attitude of the automatically controlled aircraft, an electromechanical system is used to vary the pitch attitude through the Master Sequence Selector as a function of input voltages that are preselected. To avoid transient attitudes caused by rapid response of the automatic pilot, the pitch attitude selector, although varied in discrete steps, changes the attitude gradually.

Constant Air Speed Control

It has been found necessary, in the approach sequences of the automatic flight where the aircraft is being controlled by an Instrument Low Approach System, that engine power, in addition to elevator movement, be controlled. This is done by the use of a constant air-speed control unit that maintains an arbitrarily selected air speed as the aircraft makes a descent controlled by the glide path system. It is a pitot-pressure actuated system that regulates the engine power, holding the air speed to within ±3 m.p.h.

Landing Gear and Flap Control

Automatic operation of the landing gear and flaps is accomplished by energizing servo systems through the Master Sequence Selector.

Altitude Control

In certain phases of the automatic flight, a constant barometric altitude is maintained by the automatic sequential operation of the altitude control inherent

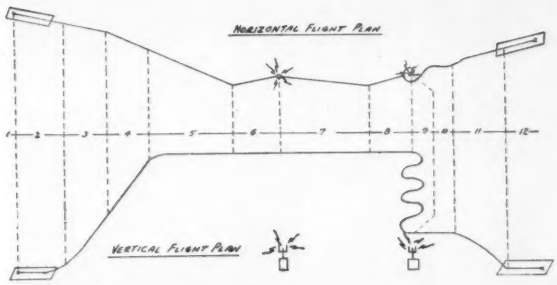


Fig. 1. Functional flight plan.

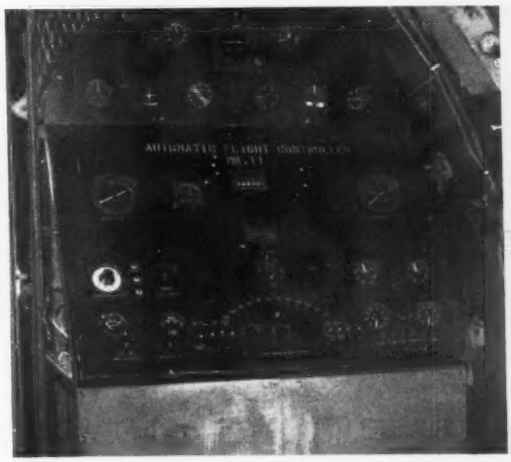


Fig. 2. Front view, control panel.

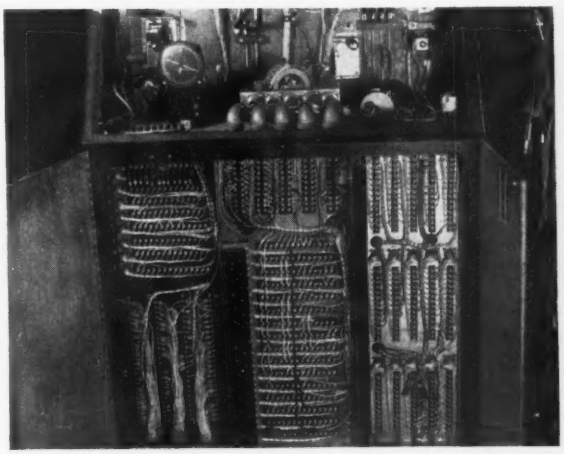


Fig. 3. Master Sequence Selector and junction box.

in the E-4 automatic pilot by the Master Sequence Selector.

Localizer and Glide Path Control

The A.A.F. Instrument Low Approach (SCS-51) or Sperry Microwave System is used to control the direction and pitch attitude of the aircraft, in con-

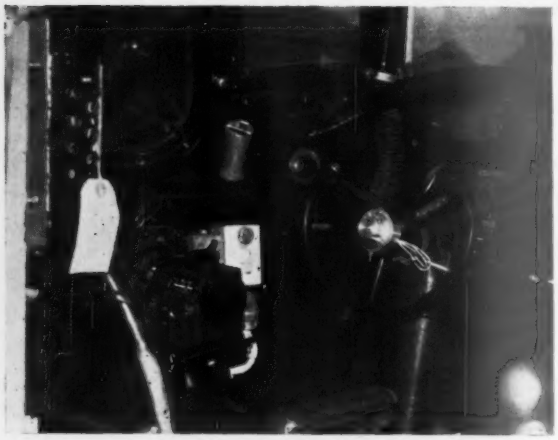


FIG. 4. View of cockpit showing manual override for power control on steering wheel.

junction with the Master Sequence Selector, during the approach and landing sequences of the automatic flight. The Sperry Automatic Approach coupling output is proportional to the azimuthal angle of departure from the beam plus the rate of angular closure. The signal to the pitch control circuit is proportional to the vertical angular displacement from the glide path beam.

In order to advance the Master Sequence Selector automatically to the successive sequences of the automatic flight, flight sensing units are used that detect the arrival at the end of a particular flight phase. They include the following:

Altitude Sensor

A modified Radio Altimeter (An/APN-1) used to actuate the Master Sequence Selector at 50-ft. altitude, 1,000 ft., 2,000 ft., and at an altitude arbitrarily selected between 3,000 and 8,000 ft. Correct range of operation is maintained by the switching of precalibrated circuits to the Radio Altimeter by the Master Sequence Selector.

Air-Mile Counter

This is a modified Air Position Indicator incorporating a Veeder-Root Counter and associated electrical circuits that actuate the energizing circuit of the Master Sequence Selector after an arbitrarily selected number of air miles has been flown.

Localizer and Glide Path Sensors

The entry of the aircraft into the localizer and glide beams are used by the Automatic Flight Controller as points of demarkation in the flight to actuate the Master Sequence Selector. They are essentially electronic amplifiers that furnish an electrical impulse to the Master Sequence Selector when the beam is intersected.

Other minor sensing functions for advancing the Master Sequence Selector are used, such as landing-gear microswitches to detect touchdown and a device for detecting the point when the aircraft passes over a "homing" radio station.

A flight, such as the one that was made recently from Stephenville, Newfoundland, to Brize Norton, England, is divided into twelve operational phases:

(1) Pretake-Off: Manual alignment of the aircraft with the runway, and flight information "fed" to the Automatic Flight Controller.

(2) Take-Off:
- (a) Take-off power provided.
- (b) Runway heading maintained by automatic pilot.
- (c) Up-signal applied to automatic pilot.
- (d) At 30 ft. altitude, the radio altimeter advances the Master Sequence Selector to position No. 3.

(3) Initial Climb:
- (a) Full power provided.
- (b) Runway heading maintained.
- (c) 1,000 ft. per min. up-signal provided.
- (d) Landing gear retracts.
- (e) At 1,000-ft. altitude the radio altimeter advances the Master Sequence Selector to position No. 4.

(4) Final Climb:
- (a) Climb power provided.
- (b) Runway heading maintained.
- (c) 1,000 ft. per min. up-signal provided.
- (d) Flaps retract.
- (e) At a cruise altitude preselected the radio altimeter advances the Master Sequence Selector to position No. 5.

(5) No. 1 Navigation Sequence:
- (a) Cruise power provided.
- (b) No. 1 preselected magnetic heading maintained.
- (c) Up-signal reduced to zero.
- (d) Barometric altitude maintained by altitude control unit of automatic pilot.
- (e) No. 1 Air Mile Counter in operation.
- (f) At the end of the preselected number of air miles, the No. 1 counter advances the Master Sequence Selector to position No. 6.

(6) No. 1 Radio Homing Sequence: In order to correct for any error caused by change in meteorological conditions, the aircraft "homes" to a radio station located on or near the desired course.
- (a) Cruise power provided.
- (b) Aircraft "homes" to the first preselected radio station.
- (c) Altitude control remains cruise altitude.
- (d) When the aircraft passes over the radio station, the Radio Compass Sensor advances the Master Sequence Selector to position No. 7.

(7) No. 2 Navigation Sequence:
- (a) Cruise power provided.
- (b) No. 2 preselected magnetic heading maintained.

(c) Altitude control maintains cruise altitude.
(d) No. 2 Air Mile Counter in operation.
(e) At the end of the preselected air miles, the Master Sequence Selector is advanced to position No. 8 by the No. 2 Air Mile Counter.

(8) No. 2 Radio Homing Sequence:
(a) Cruise power maintained.
(b) Aircraft homes on second preselected radio station which has been set up on the extension of the center line of the runway, 15 miles from the approach end.
(c) Altitude control maintains cruise altitude.
(d) When the aircraft passes over the No. 2 radio station, the Radio Compass Sensor advances the Master Sequence Selector to position No. 9.

(9) Orbit and Descent Sequence:
(a) Landing gear and flaps extend.
(b) Approach power provided.
(c) 500 ft. per min. down-signal is provided.
(d) The Radio Compass Controller is in operation. The path of the aircraft is a helix at the maximum turn radius of the automatic pilot and at a 500 ft. per min. rate of descent.
(e) At 2,000-ft. absolute altitude the radio altimeter advances the Master Sequence Selector to position No. 10.

(10) Initial Approach:
(a) Cruise power provided.
(b) Aircraft is oriented with the ILAS localizer course by the localizer sensor, and the ILAS localizer course is maintained.
(c) Approach altitude maintained by the altitude control.
(d) When the aircraft intersects the center of the ILAS glide path beam, the Glide Path Sensor advances the Master Sequence Selector to position No. 11.

(11) Final Approach:
(a) Engine power is varied by the air-speed control to maintain 115 m.p.h.
(b) Localizer course maintained.
(c) Glide Path Signal controls the elevators.
(d) Pitch altitude voltage to maintain three-point attitude.

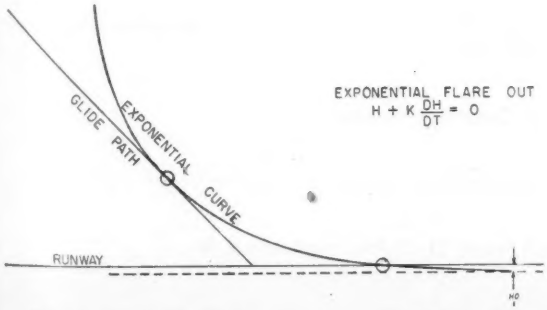


FIG. 5. Configuration of proposed exponential flare-out.

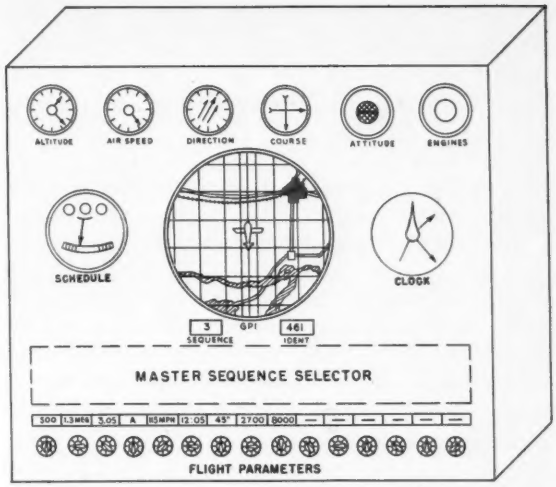


FIG. 6. Proposed control panel of Mark III Automatic Flight Controller located in navigator's position. The dials are positioned automatically to select the desired flight parameters.

(e) At 50-ft. altitude, the Radio Altimeter actuating circuit removes the glide path control and constant air-speed control and applies a 300 ft. per min. descent down-signal and final approach power.
(f) Aircraft touches down at a rate of descent, a function of the ground winds, between 200 and 400 ft. per min.
(g) At touch-down, a microswitch operated by the compression of the right landing-gear strut advances the Master Sequence Selector to position No. 12.

(12) Landing Roll Sequence:
(a) Idle power provided.
(b) Localizer course maintained.
(c) Pilot manually applies brakes to halt aircraft on the runway.

By placing different values in the "memory" of the Master Sequence Selector, the flight can be made between any two points where the required ground facilities exist.

FUTURE PROGRAM

The second phase of development is now in progress, based primarily on results of the performance of the prototype Automatic Flight Controller. It would be perhaps worthwhile to outline the program being undertaken and the form that the Automatic Flight Controller will take in the near future.

The most pressing problem with which we are confronted is satisfactory reliable automatic landing. The prototype Automatic Flight Controller, as outlined previously, makes a touch-down at rates of descent between 200 and 400 ft. per min. Methods of decreasing the rate of descent at touch-down have been investigated, and it is considered that a system for exponential vertical control by a radio altimeter is the most satisfactory solution.

Tests, originally carried out by the Germans during the early years of the war, show that manually controlled landings with varying types of aircraft have a configuration that is determined by the equation

$$dh/dt + Kh = 0$$

showing that the vertical velocity near touch-down is an exponential function of the height above the runway. The rate of descent at touch-down then becomes zero.

If the engine power during the final approach is made a function of the height of an aircraft, and the elevators are positioned to satisfy this equation, the aircraft can be made to approximate automatically an experienced pilot's action during the landing sequence. Rate of descent in this system is controlled by a computer that feeds a correcting voltage to the pitch control circuit of the automatic pilot, so that the correct relationship exists between rate of descent and height, and the air speed is varied between limits of the lift-drag curve that allows satisfactory vertical control by the elevators. The accuracy requirements of an altimeter for satisfactory touch-down velocities of less than 100 ft. per min. are of the order of ± 2.5 ft. in height and a smoothness of output that permits differentiation to detect rates of change of 1 ft. per sec.

Vertical control of the aircraft governed by the above-mentioned equation has been demonstrated successfully in England and will be evaluated as a component of the Automatic Flight Controller. The concept of a unique glide path, with the attendant problems of increasing sensitivity as the runway is approached, and the transients generated by vertical gusts, is discarded in the last few feet of the approach in the altimeter controlled exponential landing system. In actual operation, the glide path will be used down to an altitude of the order of 50 ft., where a smooth transition between ILAS glide path control and radio-altimeter control takes place.

Secondary landing problems, such as crab-angle elimination at touch-down, automatic localizer gain control, and automatic taxi control, are being attacked at the present time in current projects at the All-Weather Flying Division.

The second major problem in automatic flight control is automatic navigation. The present Automatic Flight Controller embodies radio station "homing" and air position control that does not ensure the aircraft path being within prescribed limits. The use of automatic offset computers with omnidirectional radio and distance measuring radar systems is planned, including the automatic sequential selection of offset parameters for automatic operation with successive ground stations. Automatic ground position control as a function of time is another feature that will be incorporated in the Automatic Flight Controller, with OMNI-DME and other navigation systems more suitable perhaps for the military aspect of automatic flight control.

Conclusion

It is believed that, in the next few years, it will be demonstrated effectively that the reduction in the number of variables in flight control can best be done by the use of automatic control. This is particularly true with the advent of larger and faster aircraft that do not permit the marginal control that now exists in all-weather flying. To this end, the All-Weather Flying Division is set to the task of perfecting the Automatic Flight Controller and to provide a vehicle with which systems and equipment can be evaluated in an integrated form, under all weather flying conditions.

Feature Articles Coming in the August Review

"Meeting on Wings"—A composite story of the Personal Aircraft Meetings and Discussions in Detroit, Wichita, and Dayton

"Inert Gas Installation," by H. W. Naulty, Cornell Aeronautical Laboratory

"Flight Path Control," by Paul A. Noxon, Eclipse-Pioneer Division, Bendix Aviation Corporation

"The Helicopter Control Rotor," by Joseph Stuart, III, United Helicopters, Inc.

Loss Prevention Programs in Civil Aviation

JEROME LEDERER*

Aero Insurance Underwriters

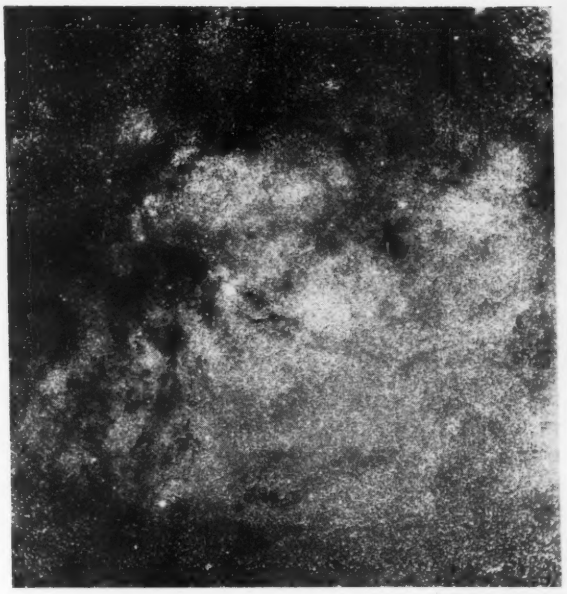


Photo by Carnegie Institute

FIG. 1. Great star cloud in scutum—Milky Way.

PART I—THE PRESENT STATUS OF SAFETY AND AN INQUIRY INTO YARDSTICKS USED TO MEASURE IT

LECTURES ON SAFETY AND LOSS PREVENTION are more often addressed to the public than to designers, engineers, and technicians. However, as long as the public associates fear and danger with flying, accidents and means to prevent accidents should be of great concern to the aeronautical engineer. His personal financial outlook would depend to a great extent on safety if the existence of this industry were solely dependent on civil aviation. Experience shows that, as accidents increase or are unduly publicized, the public loses its enthusiasm for flying with obvious consequences to production of business and costs of operation. This will be true, even while the accident rate improves, as long as the newspapers continue to headline serious accidents. The public is more impressed by the dramatic impact of headlines and gruesome photographs than they are by favorable safety rates.

A series of air-line accidents in the Spring of 1947 coupled with congressional air safety investigations and the appointment of the President's Board of Inquiry into Air Safety has served to focus attention on flying safety as never before. The aviation industry realized that its survival on a civilian basis is largely dependent on safety. The President's Air Policy Commission in its recent report entitled *Survival in the Air Age* gives to safety the following force.

"The question of safety in commercial aviation is of prime importance not only because of the importance of human life but because of its psychological effect on traffic and the effect of traffic upon the self-sufficiency of the air lines.... The disproportionate amount of publicity inevitably given air-line crashes gives an unwarranted impression that air-line travel is basically unsafe. Statistics on scheduled air-line operations compiled by the Civil Aeronautics Board show that the chances of fatality in terms of passenger-miles flown are slight."

The Commission's report does not come to any conclusion on the safety of personal flying. Unfortunately, except for the relatively few pilots and organizations that have achieved a good record, it is far from being as favorable as the air-line picture, and that is putting it mildly.

Before accepting these assertions, the engineer should inquire into their validity and significance. An investigation into the manner by which aviation safety is measured should include:

(1) The *appropriateness* of the information or yardsticks used to record safety.

(2) The *magnitude* of the records.

(3) The record *relative* to other forms of transportation.

(4) The *trend* in the safety record.

By Point One—the appropriateness of the yardstick—I mean that we should try to find a true and practical yardstick, preferably one that leaves a legible mental image and that measures life expectancy or freedom from injury. It may be based on passenger fatalities, fatal accidents, near fatal accidents, per mile, per hour, per aircraft, per passenger-mile, per flight, or whatever is accepted as an honest standard.

By Point Two—the magnitude of the records—I mean the significance of the record. How does it match against the ordinary hazards of living and the

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* Engineering Department.

public's concept of an acceptable degree or magnitude of safety? Are there sufficient units to allow the mathematical laws of large numbers to operate?

By Point Three—the comparative record—I mean how the record in flying compares with safety in other means of transportation. This is necessary to satisfy the public's demand for comparative statistics and also for the evaluation of one air line or one airplane against others or to compare personal flying with air-line flying. There is considerable doubt as to whether one yardstick is appropriate for all forms of transportation or for all forms of flying.

By Point Four—the trend—I mean the fluctuation in the record to determine whether it is getting better or worse, both in the absolute sense and in comparison with other systems of transportation. For example, if certain yardsticks are used, it is possible to show that the safety of air lines has been approaching the safety of Class I railroads, not so much on account of improvement in air-line safety but because the railroad record is deteriorating.

Having raised these issues, I shall not attempt to resolve them, but I propose to discuss them briefly with the hope of arousing further thought and discretion in the consideration of accident statistics.

Concepts of Public Safety

The yardstick commonly used to measure safety in transportation is passenger fatalities per 100 million passenger-miles traveled. This may be a result of habit established to measure railroad safety. It is probably a good criteria for railroads because in a typical railroad accident usually only a small percentage of the passengers are killed. When a passenger wishes to assess his exposure to danger while railroading he might reckon: I am one of many millions of railroad passengers. What are my chances of being killed on this trip? When a fatal accident occurs there is still a reasonable chance of survival. The percentage of total passengers killed in past years is A and their exposure was an average of B miles per passenger. How many miles must I ride as a passenger before I'll be killed? The answer for 1946 would have been about one chance in 560 million passenger-miles or 0.18 per 100 million passenger miles.

That is a good record, and it seems to me to be based on a sound yardstick. In the absolute sense no reasonable person would hesitate to ride in a railroad train with his chances of being killed at one in 560 million. In the relative sense using the same yardstick, the safety of traveling by bus is about the same as by railroad; the domestic air-lines rate on the same basis of fatalities per 100 million passenger-miles is about eight times that of the railroads but about 60 per cent better than traveling in a passenger automobile or taxicab. The public does not hesitate to ride in autos or cabs. (See Table 1.)

Here I should like to introduce a different and possibly new concept of safety, especially absolute safety. When dealing with minute parts of an astronomical figure, like 100 million passenger-miles, we should think in terms of panoramic vista or magnitudes rather than of numbers. Let us assume that there are 100 million stars in the Milky Way. (See Fig. 1.) 100 million stars or 100 million passenger-miles: does the absence of one or ten make any difference? If we took away 1.2, 0.18 or 2.5 stars, or even 5.0 stars, would the difference be noticeable? If one had an income of a million dollars per year (after taxes!) would it make an appreciable difference in one's economy if two dollars or seven were spent for a necktie? He would certainly be no less a millionaire. Similarly with air-line travel. Should it make any difference in the attitudes of the public toward air travel if the fatality rate were one or 5 in 100 million passenger-miles? The *magnitude* of the safety record is about the same in either case. The public does not hesitate to ride passenger cars or taxicabs. The magnitude of their safety is not so good as the air lines yet is acceptable to the public. Therefore, it is fair to conclude that the magnitude of safety achieved by the air lines would be fully acceptable to the public, but the public receives a distorted picture of air-line safety from the press and, therefore, fails to appreciate the true magnitude of its saftey.

TABLE 1

Transportation Accident Death Rates 1944–1946 from Accident Facts 1947 Published by National Safety Council

Passenger automobiles and taxi	2.7	Average death rate 1944–1946 per 100 million passenger-miles
Buses	0.19	
Railroad passenger trains	0.21	
Scheduled air transport	1.7	

An acceptable magnitude depends on the mores of the people and circumstances. In some parts of the world life is held in less regard than in others. Also, impatience, pleasure, profit, cost, or discomfort often impel people to accept a more dangerous form of transportation in preference to a safer form. For instance, Porto Ricans migrating to and from New York do not appear to discriminate between the first class and the substandard aircraft operators. Apparently, the magnitude of safety achieved by the substandard operators is acceptable to them under their circumstances.

This concept of magnitude of safety instead of numbers or rates should dissolve fear engendered by numerical comparisons of minute quantities of danger such as comparing railroad safety with air-line safety and, if properly presented to the public, may assist in combating the effect of adverse publicity given to air-line crashes.

This concept of magnitude or panoramic vista of safety also eliminates peculiar variations that result from our manner of keeping safety records. For instance the *calender* year 1939 shows a record of 1.2 air-line passenger fatalities per 100 million passenger-miles flown (domestic); the *fiscal* year 1939 (July 1 through June 30) shows zero passenger fatalities or a perfect year. The difference between removing 1.2 particles from 100 million or removing none is difficult to visualize.

We can use this concept from here on while discussing other safety yardsticks. We started with the yardstick of fatalities per 100 million passenger-miles. I accept this as a reasonably good yardstick for railroads. But fatal accidents involving aircraft usually result in a much larger percentage of occupants being killed than in a train so I believe that a better yardstick is to reckon flying safety in the same terms as might a member of the flight crew. A pilot could not accurately measure his air-life expectancy on the basis of passenger-miles because he rides whether or not passengers are being carried. He should reckon his exposure to fatality on the basis of pilot fatalities per hour or miles flown or per thousand hours or miles flown. The true standard of safety should be life expectancy which for aircraft is more nearly akin to hours or miles one has left to live while flying than so many passengers traveling so many miles (Fig. 2).

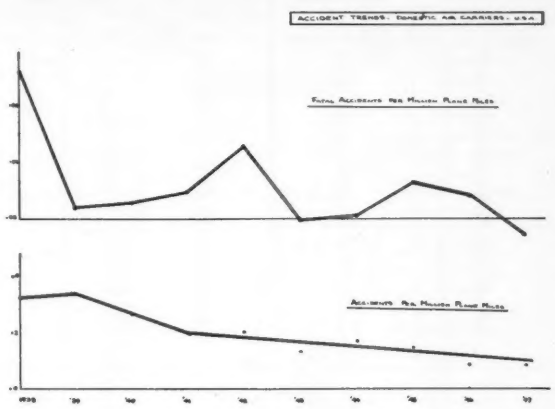

FIG 2.

An air-line passenger using this approach could figure on flying domestically 62,740,565 miles before being involved in a fatal accident on a certificated air line. This is based on the domestic air-line experience in 1947, which on the accident mileage basis is the best on record. There is an appreciable difference in magnitude between this and the year 1938, the worst air-line year since C.A.A. has kept records. In 1938 the record was one fatal accident in 13,679,660 miles flown. However, I defy anyone to discern one part in 13 million. I would guess that it is about on par with the hazard of driving a passenger car at night in the country and therefore is still acceptable to the public; it is of satisfactory magnitude.

The yardstick I prefer is the number of all accidents per aircraft mile or hours flown. I discard the use of *fatal* accidents and prefer to consider all operational accidents because I feel that the difference between a fatal and a nonfatal aircraft accident is at present too often a matter of luck. For the years 1943–1947 this averaged one accident per 8 million aircraft miles. Could I drive a car 8 million miles without at least one serious accident? This magnitude of safety is well within my concept of my life expectancy. And there is sufficient similarity in overall operating procedures so that I would not make any appreciable discrimination between air lines, although I know, of course, that there are recognizable differences in management and attitudes.

Some European aviation insurance experts are considering as a yardstick the number of fatal accidents per thousand flights. This might be an honest yardstick when it is possible to agree on a definition of a flight and then to obtain the statistics on the numbers of flights.

Another way one might gage his absolute safety is to determine the proportion of air-line passengers that are killed in air-line accidents. In the 5 years ending with December 31, 1947, the rate has been 421 passengers killed for 39,397,000 carried or a rate of almost one per 100,000. (In 1947 the rate was 1.6 per 100,000 passengers because of larger aircraft being used and more occupants killed per crash.) That this is well within acceptable magnitudes (though far inferior to the railroad or bus record*) is shown by comparisons for 1945 taken from the *World Almanac* (see Table 2).

TABLE 2

Death Rates by Chief Causes for 1945 per 100,000 of Populations (from *World Almanac*—1948 Edition)

(1) Accidental deaths = 72.7
(2) Accidental drowning = 4.3
(3) Motor vehicle accidents = 21.3 (includes pedestrians as well as occupants)
(4) Conflagration = 2.7
(5) Homicide = 5.6
(6) Air transport = 2.2 (the author feels this figure is too high and probably incorrect, and is checking further the basis of this figure)

The air-line safety record by any yardstick appears well within magnitudes of safety acceptable to the public. Nevertheless, the air lines have a moral obligation and, as long as there are newspapers, a financial incentive to continue to make it safer.

I have not attempted to analyze the causes or nature of air-line accidents or to discuss the incidence of near accidents, severe injuries, and other related data.

Air-line accidents due to fires in flight or structural failure are important but of a transitory nature. The outstanding factor in producing fatal or potentially fatal air-line accidents over a period of years is the error made in approach and landing during poor weather conditions. If this factor were eliminated, about 40 per cent of fatal or potentially fatal air-line accidents would go with it. Further improvement will result in the future by advances in methods for selecting personnel, refinement in training methods and maintenance of pilot proficiency, the establishment of improved systems to obtain closer control over the quality of performance, and fundamentally a recognition by designers of the fact, easily proved, that pilots and mechanics are human. Being human they are subject to fatigue,

* In 1946, Class I Railroads carried 790,129,518 passengers, 115 were killed. Intercity buses carried 872,200,000 passengers (excluding school, charter), killed 140 passengers. These indicate a rate of one fatality in about 6½ million passengers carried. In the same year 15,400 occupants were killed in passenger automobiles and taxicabs.

Age	Aviation Death Rate per 1,000	Age	Aviation Death Rate per 1,000
21	23	41	8
22	21	42	7
23	18	43	7
24	16	44	7
25	15	45	6
26	14	46	6
27	13	47	6
28	13	48	6
29	12	49	6
30	12	50	5
31	11	51	5
32	11	52	5
33	11	53	5
34	11	54	5
35	10	55	5
36	10	56	5
37	10	57	5
38	9	58	5
39	9	59	5
40	8		

FIG 3.

strain, forgetfullness, and other causes of error in action. Designers must give as much emphasis to the human factors as to performance and structural integrity.

Employee Safety

Before leaving the air-line safety picture we should touch upon the methods used to measure the safety of air-line personnel. I mentioned before that the pilot and other crew members should reckon their safety on the basis of pilot fatalities per hour of exposure (per 1,000 hours is commonly used). The Actuarial Society of America has published a death rate of about 0.005 per thousand hours of flying or about one fatality per 200,000 hours for an air-line pilot. Since he flies no more than 1,000 hours per year, he would have to fly 200 years before meeting with a fatal accident.

The yardsticks used to measure the safety of air-line ground personnel are the same as used for all other industries: frequency of accidents and severity of accidents based on man-hours of exposure. Some air lines have achieved outstanding records, but in both respects the air transport industry as a whole is not doing so well. The number of disabling injuries per 1,000,000 man-hours is 17.55. The rate for all industries is 14.16. The severity rate is based on days lost per 1,000 man-hours. Air transport is again doing poorly with a rate of 1.92 against an all-industry average of 1.28. Even the shipbuilding, petroleum, and iron and steel products industry do better than the air lines. On the other hand, the aircraft manufacturing industry does very well, being among the safest industries in which to work. (See Fig. 3.)

Nonscheduled Air Carriers

In 1946 the nonscheduled air carriers were involved in eight fatal accidents (killing 19 crew members and 58 passengers). Their fatality rate based on the C.A.B. estimate of 375,000 hours flown is therefore 0.21 fatal accidents per 10,000 hours. Scheduled air carriers had a rate of 0.04 per 10,000 hours or five times better than the nonskeds. However, there is great variation between the quality of management and operation of nonscheduled air carriers. Some have excellent records and should not be linked with the whole lot.

Mishaps such as taxiing into buildings or other aircraft, wind damage, losses by ground fire, damage to aircraft done by trucks and by scaffolds, and other sources of aircraft losses have not been included here because space would not permit it. However, I gave this paper the title of "Loss Prevention" instead of "Safety" to bring in the broader field of overall loss prevention. These problems are usually handled within the companies, sometimes spurred by insurance organizations.

Personal Flying (Including Charter, Fixed-Base Operation, Private, Industrial Aid, Etc.)

The public cannot trust accident statistics on personal flying to assess its risk in taking a flight with any random pilot that comes along, as they do with taxicab drivers or drivers of automobiles. The public would be safe if it could differentiate between the good and the bad. We all know of pilots with thousands of hours have fine safety records, and there are flying school and charter operators with wonderful safety records. The large corporations owning executive-type aircraft have established excellent safety records. In personal flying discrimination is necessary for safety when one chooses to travel that way.

The accident rate in personal flying is much more difficult to evaluate than in scheduled air-line transportation because the exposure records, such as hours or miles flown or passenger-miles or even the number of certificated aircraft and pilots, are not accurately known and can only be estimated.

The C.A.A. has initiated a method for obtaining hours of exposure by a sampling process. This is a logical and commendable approach.

The results of the survey indicate that in 1946 there were about 9,800,000 hours flown in nonscheduled operations. The C.A.B. estimates that of this total the nonscheduled air carriers flew 375,000 and nonair carriers 9,425,000 hours. A breakdown of the latter was made by the C.A.B. Because of the overlapping use of aircraft, a number of assumptions, some of them probably open to debate, had to be made before arriving at the figures in Table 3.

The scheduled air lines have an 0.04 fatality rate or about 30 times better than personal flying, excluding instruction.

An outstanding contributing factor in producing this unfavorable record is the recklessness of youth. Fig. 4 shows how an increase in 5 years over the reckless age improves the record by 70 per cent.

TABLE 3

Kind of Flying	Estimated Aircraft Accidents per 10,000 Hours		
	Fatal	Nonfatal	Total
Instructional	0.3	4.8	5.1
Noncommercial	1.3	10.8	12.1
Commercial and Miscellaneous	1.7	12.1	13.6

Probably the nearest accurate figure in personal flying is the number of registered aircraft. The average number in 1946 was 57,000. In that year, the latest year for which complete figures are available, almost 1,200 people were killed in 690 fatal accidents. Therefore, one in every 85 airplanes was involved in a fatal accident, a shameful ratio considering the limited use these airplanes get. Bad as it is, this is some improvement over the prewar (and pre-C.P.T.) years when one out of every 55 airplanes was involved in a fatal accident. From the advent of the C.P.T. program to the end of the war, the record was much better than before or after (about one in every 115 aircraft involved in a fatal accident). This was due to the rerating of instructors and tight control by C.P.T. during the very active years of 1940–1942 and the restrictions, gas rationing, and use of only designated airports during the later years of the war. Even on the basis of the best record, if there were as many personal aircraft as automobiles we would have about 300,000 fatal accidents per year and kill 500,000 people. I use this comparison, ridiculous as it may be, to emphasize the point that if the public knew the true rate of fatalities in private flying, this class of flying would not have much chance of survival. The accident rate in personal flying is not of a magnitude that the public would accept if it knew how bad it was. It is the reverse of the air-line picture, where the accident rate is good but the public looks askance.

The stall spin must be removed as a cause of fatal accidents, but even with that out of the way, the fatal accident rate would still be bad. Stall spins account for about 45 to 50 per cent of fatal accidents, so their absence would involve about one aircraft in every 150 aircraft in a fatal accident instead of one in 85.

For purposes of comparison about one in every 3,000 automobiles is involved in a fatal accident each year.

I mentioned before that the fatality rate of air-line pilots is about 0.005 per 1,000 hours. The comparable figure for the private pilot is difficult to determine accurately, but according to the Actuarial Society of America it was about 0.125 per 1,000 hours in the period 1937–1940, or 25 times more dangerous than for the air-line pilot. A private pilot flying as many hours per year as an air-line pilot should be dead statistically in 10 years. The rate for commercial pilots was about 0.045; the rate for instructors, 0.05. The closely supervised C.P.T. program improved the fatality rate for both students and instructors to about 0.01 per 1,000 hours, which is a remarkable improvement. The Actuarial Society of America says that "there is great improvement in safety where close Governmental supervision is exercised with little or no tendency to improvement in those types of flying where there is no supervision other than the general requirements of Civil Air Regulations."

The fatality record in personal flying is bad enough, but the overall loss record is also poor. Each year about one in every eight aircraft are involved in an accident reported to the C.A.A. However, this does

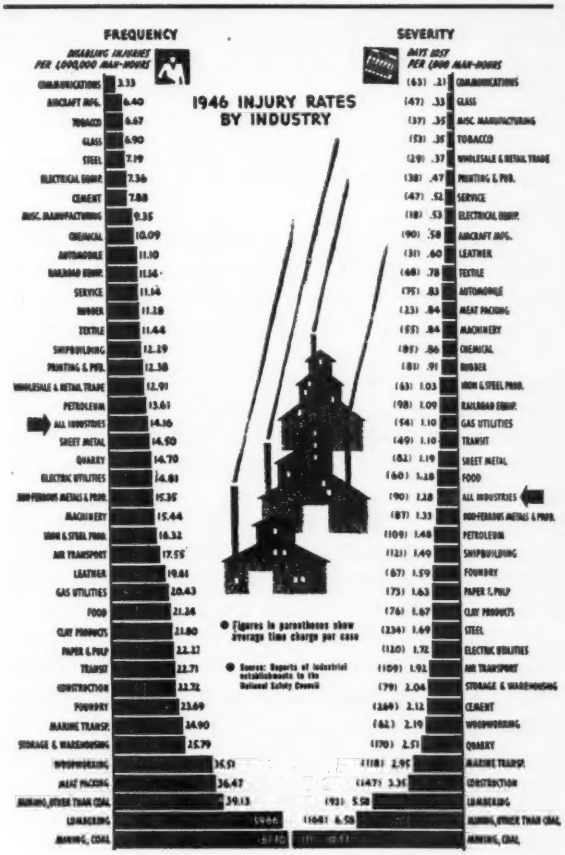
FREQUENCY
SEVERITY
1946 INJURY RATES
BY INDUSTRY
● Figures in parentheses show average time charge per case
● Source: Reports of industrial establishments to the National Safety Council

FIG 4.

not include losses due to windstorm, hangar fires, carelessness, and numerous other causes of ground damage. The truer figure is that one in every five and possibly one in every four aircraft are involved in loss of some kind each year.

In personal flying, as indicated before, the fatality record can be reduced by almost 45 per cent if the stall spin could be averted. This and a campaign against low flying to reduce collisions with trees, mountains, and other objects on the ground would attack another 25 per cent of the fatal accidents occuring in personal flying. The rerating of instructors and the general tightening of training procedures appear necessary. As in air transport design, the design engineers should recognize the problem of safety created by human limitations and carelessness.

Fatality records for both personal flying and air-line flying would be improved if the work of the Crash Injury Research Division of the National Research Council were more adequately encouraged, supported, and followed by the aviation industry.

Part I of this discussion summarizes as follows. The completely proper yardstick used to measure safety in aircraft operations has not yet been found and further exploration is desirable. But whatever yardstick is selected, its principal use will be to determine trends rather than to assess one's exposure to accident, inas-

much as the air-lines record for safety is far within the public concept and acceptance of safety in other fields of activity. Air-line safety is of the same general magnitude as any other form of transportation. The record could be improved greatly by attacking one or two outstanding causes. The injury record for ground personnel employed by the air lines is poor relative to other industries.

The average record for nonscheduled air carriers is not so good as the air lines but great variation in company management within that group invalidates the use of rates or statistics to secure a true picture of their safety. This is also true of personal flying where safety is dependent on discrimination, but there are sufficient numbers in this category to conclude that as a whole personal flying has a long way to go before it will be completely accepted by the public as a safe means of transportation.

May I conclude by again quoting from *Survival in the Air Age*, the report of the President's Air Policy Commission: "No phase of commercial aviation is more important than safety."

PART II—Loss Prevention Programs

When I started this survey of loss prevention programs, I discovered that I had a bear by the tail. The need for greater safety has been widely recognized, and aviation is blessed by at least 30 planned and directed crusades or scientific efforts to promote its safety. Associations composed of aircraft manufacturers, operators, and airmen sponsored by the aviation industry devote an appreciable share of their activities to safety. Other industries allied with aviation, such as the oil and insurance companies, initiate and carry on loss prevention campaigns. Publishers of several aviation periodicals have established policies that require articles on safety in every issue, and the publishers of other aviation magazines carry articles on safety at frequent intervals. Speciality organizations such as the National Fire Protection Association, the National Safety Council, and the engineering societies are constantly issuing studies, codes, and recommendations on safety or loss prevention. And on top of all these are the omnipotent Governmental bodies with safety as a principal objective.

I shall not now presume upon your patience to describe the work of these organizations even briefly, since I fear I might endanger my own safety. A digest of the various programs will be available in the near future.

As an example of the scope of the problem, Governmental interest in safety is represented by at least eight agencies, each of which has several subdivisions working on that problem. These agencies are the Department of Commerce, the C.A.B., ICAO, the National Association of State Aviation Officials, the National Advisory Committee for Aeronautics, the Coast Guard, the Army, and the Navy. In addition, there are temporary Governmental bodies established at intervals to investigate safety, such as the Congressional Committees and the President's Special Board of Inquiry on Air Safety. To cover only the Governmental activities would take more than my total available time. I shall limit my comments to a survey of trends and deficiencies.

The posters, the codes, the safety studies, the manuals, and the numerous other literary products represent only a small part of the available output of safety efforts. There are other activities that cannot be adequately represented in literary form. One of these is accident investigation. A typical instance to show how that important and fascinating work results in safety appears to be in order.

A large airplane on a test flight crashed into a body of water shortly after take-off. The crew of five were fatally injured, and, of course, the airplane was completely destroyed. The airplane had left the airport abruptly and followed an erratic climbing and diving flight path. One of the crew lived long enough to relate that the pilot had been exerting every effort to push the wheel forward but could not. The components were salvaged from 35 ft. of water for examination. During the course of lifting an aluminum housing forming a part of the pilot's elevator control unit, a nickel-steel machine screw fell out. This screw was of a type used to fasten the instrument panel. It was badly marred, as were other screws found in the salvage, but a supposition was advanced that this screw might have dropped through a lightening hole in the box surrounding the chain that actuated the elevators. Through investigation using microscopic and spectroscopic analysis, followed by tests, proved conclusively that this screw only $^5/_8$ in. long and $^1/_8$ in. in diameter had caused the loss of control. Thereafter the manufacturer masked the lightening holes to prevent foreign matter from dropping into the control unit.

Loss prevention programs can be divided into the well-known three E's of safety: Engineering, Enforcement, and Education. (I have advocated a fourth E to represent the Energy required for all this!)

Incentive programs, such as the certificates of good practice awarded to airports that meet minimum safety requirements, fall under the general heading of education, because a certificate or other award is received for accomplishment.

Enforcement programs may vary from humorous humiliation, such as making a flying student measure off a runway with a foot rule for not using its full length, to revocation of a certificate, fines, and jail.

Enforcement programs, however, are mostly punitive in the serious sense, and in personal flying there has been a strong shift from, and with the concurrence of, the C.A.A. to local agencies such as State Police and even county organizations. The C.A.A. obviously is not so well equipped to enforce the Civil Air Regulations on a grass roots basis as are the states. However, local enforcement to be effective requires special training. A few cases of injustice have been reported, as when a lost pilot trying to determine his location by flying low over a railroad station was arrested for buzzing. The

State Aviation officials, notably those in Pennsylvania, Michigan, Indiana, and Idaho, have inaugurated excellent programs for training local police in the ways of aviation. In Pennsylvania and Michigan and perhaps other states, State Troopers are also being trained in aviation accident investigation, especially to procure data for crash injury research. The State Aviation Officials also interest themselves in reducing ground losses from windstorms, fire, taxiing, and carelessness. Personal flying should benefit from their activities if the programs of the future are extended and follow those now under way.

Safety enforcement programs relating to manufacturers and air-lines continue to rest with the C.A.A. A program begun last year to improve the practices of some of the nonscheduled operators apparently has not been wholly successful, judging by reports on some of the recent accidents. Certified air lines are occasionally penalized by the C.A.A. Air lines have enforcement programs of their own in agreement with the unions.

It is generally conceded that engineering and education are much to be preferred to enforcement. A tremendous amount of engineering to improve safety is underway. In air carrier design, emphasis is now on the problems of fitting the cockpit and controls to human limitations especially during emergencies. This human engineering also includes studies on crash survival, crew selection and coordination. Programs have been laid out to attack the fire problems, crash rescue, and problems associated with the approach and landing of aircraft in bad weather.

A scientific study to improve maintenance is long overdue. Maintenance considerations in several aircraft, both air line and personal, appear to have been based on the assumptions that the mechanic is like a laboratory technician with unlimited time and patience to take apart, study, adjust, and put together.

In personal flying the most prominent technical program at present is one to encourage the installation of stall warning indicators. This coupled with the development of weaponless cockpits so that occupants can walk away from survivable crashes should be highly effective in reducing the fatality record. The quiet but effective crash injury research program at Cornell is also making headway, sometimes against discouraging odds. Much still remains to be done in personal aircraft. For example, standards of visibility from the cockpit have yet to be established; the layout of many cockpits presupposes that all pilots are as studious and attentive to detail as the engineers who design them. Last year at the I.A.S. Symposium on Personal Aircraft I mentioned that the engineer had accomplished a good job in securing structural integrity, stability, controllability, and power-plant reliability but that he was generally not equipped by education or training otherwise to design safety into the airplane from the standpoint of human error.

I said: "There is a popular feeling in aviation that most fatal accidents are due to deliberate recklessness. The pilot who kills himself by buzzing, low acrobatics, and exhibitionism is of little concern to the engineer. But the truth is that less than 35 per cent of the fatal accidents can be attributed to extreme recklessness. This leaves the engineer with a *target* of 65 per cent of the fatal accidents to eliminate.

"Most of these fatal accidents will be caused by human failure, like flying into uncertain weather, failure to observe wires, operating the wrong lever or switch, and so on. Some of these accidents might be called the result of a reckless action, but they are probably no more so than common everyday actions such as burning toast, jaywalking, or overeating—that is, *they are the results of normal human activity*. There is strong evidence that private pilots are normal human beings. Pilots are forgetful, absent-minded, awkward, nervous. They do not maintain top proficiency as pilots. They disregard elaborate instructions, and, under conditions of stress, they should not be expected to function as well as test pilots or air-line pilots or well-trained military pilots. They do not always practice good airmanship.

"The engineer should design for this type of normal person, not for the test pilot or air-line pilot, but unfortunately, *the engineering approach to this phase of safety suffers from the basic training of an engineer*. The engineer has been molded into a relatively analytical careful person who takes great interest in studying highly technical literature and who applies himself with great diligence to an operating problem. His laboratory work in college also militates against the broad approach to safety because he learns never to operate a switch or lever until he is 'letter perfect' in its function. Moreover, he reads his instruments carefully all during the experiment, and he believes that all reasoning human beings would do likewise—even in an emergency.

"An engineer may point to a manual that he had prepared for an airplane and say: 'If the pilot had followed instruction 6 on page 30, the accident would not have occurred.' In my opinion, the size of a manual is an index of the engineer's inability to avoid pitfalls and booby traps. It is a way for making up a deficiency in design just as the laws in the Bible and in Criminal and Civil Codes are an index to our human weaknesses. The engineer is blinded by his own literacy. He should recognize that even a car operator seldom reads a manual all the way through, let alone consults it while operating the car. And when a man learns to fly, he should be regarded as being illiterate.

"The designer should remember that the average person for whom he must design the airplane is careless, impatient, lacks the time to maintain pilot proficiency, and is not accustomed to exercising continual conscious judgment in the operation of mechanical contrivances. In brief, the private pilot should not be expected to exercise the airmanship required of military or air-line pilots."

Much to my surprise an air-line pilot criticized me strongly for intimating that air-line pilots were literate or any less prone to human error than other pilots!

This leads to the most important of the three E's in safety—Education. An immense amount of aviation safety literature has been prepared. There are pamphlets, posters, motion pictures, safety codes, and books. They are almost always directed at the pilot. He is subjected to a continuous bombardment of safety signs and slogans. By and large they reflect the weaknesses and deficiencies in design or especially training which he is asked to overcome. The well-trained pilot should not have to be reminded continually to be alert against collision, to guard against propeller hazards, not to fly cross country without a flight plan or to check his fuel supply. Perhaps some of the money and energy being spent on improving the pilot might give greater value if directed toward the design engineers, the instructors, and even management.

They certainly are no less human than pilots and therefore should eventually succumb to a safety program directed at them. It is obviously not safe to design rudder pedals that jam and cause a fatal accident because the pilot is wearing cowboy boots or a girl wears high heels or to invite confusion by placing the carburetor heat button alongside the mixture control. It is unwise for management to expose the public to such design errors. The instructor already plagued by *natural* pitfalls must also train his students against man-made ones.

Safety posters should be hung on the walls of design offices calling attention to many details that a designer might not know or overlook. For instance, I can visualize a poster with a background of feathered propellers, cumulus clouds, thumbs, and gremlins carrying a jingle:

A pilot in mental commotion
Thumbs manuals with great emotion.

An instructor who allows a trainee to fly cross country with inadequate experience or who fails to impress his student with the many things he must know for safety other than being able to take off and land certainly is open to an educational campaign.

A program designed to improve the instructor would have to be dignified so that the instructor would not lose face, but it should be made psychologically as attractive as the posters designed to warn pilots against buzzing.

The manufacturers of stall warning indicators might prepare a poster with:

Pilots who on their seats depend
Eventually up to heaven ascend.

There are sizable sectors of aviation which have not been subjected to a concentrated effort to improve safety. For example:

(1) Crop dusting is probably the most hazardous form of commercial flying and should be easily susceptible to considerable reduction in danger.

(2) There is a great need to encourage manufacturers of complicated aircraft to insist that purchasers be thoroughly checked out.

(3) The owners of many large expensive aircraft often spare no money or effort to provide top-grade maintenance of the airplane but do not recognize the equal necessity for maintaining top-pilot proficiency.

Air lines conduct many safety programs, but they need a program designed to impel employees to share their information with others. Information that leads to safe operations should be common property. Technicians are all too likely to be close-mouthed, and I feel that air lines are suffering both in safety and efficiency from close-mouthed technicians in administrative posts. These men usually are extremely conscientious, so it should be relatively easy to formulate a program that would convince and train them to pass on information to others who can use it. This and continuing programs to keep pilots proficient, especially in emergency procedures, should be effectuated promptly by air lines that do not have these programs. The recent appointment of safety specialists by some air lines and a few manufacturers is an encouraging step. One air line has put safety on the same basis as operations and maintenance.

The engineer has made cunning, clever use of materials and natural forces in his attempts to perfect the art of flying. Just as there are natural forces, so there are natural weaknesses, especially human weaknesses which the engineer must also recognize. Gravity is always striving to strike the airplane down; nothing less than perfection must be the goal, because in civil aviation safety is synonymous with survival.

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The Application of Gas Turbines to Aircraft*

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SUMMARY

The decrease with altitude and flight speed of the specific fuel consumption of aircraft turboengines may, in general, be approximated by an inverse power law,

$$S.F.C. = K/V^n \qquad (1)$$

where K is a function of the component efficiency levels, the type of engine, and the altitude, and $n = 0.85$ for the average current turbojet engine and 0.1 for the average current turboprop design.

An analysis based principally on the above shows *quantitatively* the range benefits to be derived by turboengine-powered aircraft from: (a) cruising at high altitudes, (b) cruising at high indicated cruising speeds, and (c) using small wing aspect ratios.

There is a maximum achievable range for each weight class of turbojet aircraft. It is 3,300 miles for 60,000-lb. aircraft using current jet engines and slightly greater for larger aircraft.

The use of an adjustable exhaust area will not increase the maximum achievable range of current turbojet aircraft but will make possible the realization of "high-altitude" ranges at low altitudes.

A comparison of the performance of aircraft powered by reciprocating, turboprop, and turbojet engines indicates that for a maximum cruising altitude of 35,000 ft.:

(a) Aircraft with top speeds below 335 m.p.h. achieve their maximum range when powered by reciprocating engines.

(b) Aircraft with top speeds above 610 m.p.h. achieve their maximum range when powered by turbojet engines.

(c) Aircraft with top speeds in-between these two limits in general achieve their maximum range when powered by turboprop engines.

(d) Aircraft designed for extreme ranges greater than 9,500 miles have highest top speeds when powered by reciprocating engines.

(e) Aircraft designed for extreme ranges less than 2,500 miles have highest top speeds when powered by turbojet engines.

(f) Aircraft designed for an extreme range between 2,500 and 9,500 miles have highest top speeds when powered by turboprop engines in general.

INTRODUCTION

"THE APPLICATION of Gas Turbines to Aircraft" is a broad subject. It would take many more pages than we have written here to describe adequately its many facades: the operational peculiarities; the changed emphasis in aircraft development; the many promising thermodynamic cycles around which gas turbines can be developed; the potentialities of mixed power plant installations—i.e., reciprocating engines and turbojets in parallel or turboprops and turbojets in parallel—and so on. We have only undertaken to present what appear to be the more interesting aspects of Westinghouse studies of the relative performance of aircraft powered solely by current turbojets, turboprops, or turbosupercharged reciprocating engines.

Before examining these studies, it would be well to review briefly the inherently different qualities of gas-turbine and reciprocating engine power plants. The basic differences between the two types of power plants may be classified into five main groups:

(1) *Aerodynamic:* Turboengine installations tend to be cleaner aerodynamically.

(2) *Weight:* Turboengine installations are lighter.

(3) *Fuel Consumption:* Turboengines tend to have a higher fuel consumption.

(4) *Output:* The output of turboengines varies differently with altitude and flight speed.

(5) *General:* Turboengines tend to be relatively constant speed machines with a low level of vibration.

Table 1 compares these characteristics in more detail.

Aerodynamically, turboengines have the advantage of smaller frontal areas, consequently requiring smaller nacelles when installed out on the wings; they require a negligible amount of cooling power to be supplied; and, in the case of turbojets, they conveniently provide a more efficient propulsive means for high-speed flight. Fig. 1, comparing the propulsive efficiencies of propellers and current turbojets at various flight speeds, enlarges on the last point. At speeds above 715 m.p.h. at sea level and 650 m.p.h. at 35,000 ft., current turbojet designs make available superior propulsive efficiencies. The propeller data that have been incorporated into Fig. 1 are the best likely to be obtained in the next few years.[1] Note, on the other hand, that the low jet-propulsive efficiencies occurring during the

FIGURE 1 VARIATION OF PROPULSIVE EFFICIENCY WITH AIR SPEED

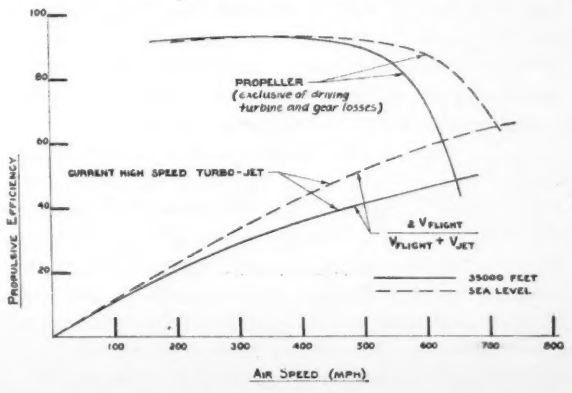

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TABLE 1

Basic Advantages and Disadvantages of Current Aviation Gas Turbines As Compared with Reciprocating Engines

Advantages	Neutral Characteristics	Disadvantages
(1) Aerodynamic		
(A) Smaller nacelles possible		
(B) Negligible cooling power required		
(C) High-speed jet more efficient propulsive means than propeller at high flight speeds (see Fig. 1)		High-speed jet less efficient propulsive means than propeller at lower flight speeds as during take-off
(2) Weight		
Lighter (specific weights including propeller and gear weights based on maximum static ratings)		
Turbojet: 0.4 lb. per lb. thrust		
Turboprop: 0.85 lb. per equivalent shaft hp.		
Reciprocating engine: 1.7 lbs. per shaft hp.		
(3) Fuel Consumption		(A) Best specific fuel consumption is, in general, poorer
	(B) Best specific fuel consumption occurs near maximum output. (Best specific fuel consumption occurs at about half maximum rating for reciprocating engines)	
	(C) At a given flight speed, specific fuel consumption tends to decrease with altitude (see Fig. 2)	
	(D) Specific fuel consumption tends to decrease with increasing flight speeds (see Table 2)	
(4) Output	(A) Variation with altitude in-between that of unsupercharged and reciprocating engines (see Fig. 4)	
	(B) At a given altitude and varying cruising speeds, turbojets behave as essentially constant thrust machines; current turboprops, as machines whose power output increases slowly with speed (see Fig. 5). (Reciprocating engines are constant power output machines)	
(5) General		
(A) Low power-plant vibration		
(B) Relatively constant engine speed over wide range of output		
		(C) High engine speed (advantageous, however, for generator drive)

relatively low speeds of take-off and climb periods will always tend to penalize jet aircraft with regard to these performance characteristics.

From the point of view of weight, turboengines are lighter, a specific weight of 0.4 lb. per lb. thrust and 0.85 lb. per equivalent shaft horsepower being obtainable with reasonable sizes of turbojet and turboprop engines, respectively, as compared with 1.7 lb. per shaft horsepower for reciprocating engines.

The best specific fuel consumption of current turboengines is somewhat poorer than that obtainable with reciprocating engines. The fuel consumptions are not strictly comparable, however, because they occur at different percentages of the maximum output of the power plants. Whereas reciprocating engines are most efficient when operating at about half their maximum power, turbomachines achieve their minimum specific fuel consumptions at outputs close to their maximum. Over and above this, as compared with the relatively fixed best specific fuel consumption of reciprocating engines, that of gas turbines tends to decrease with increasing altitudes and increasing flight speeds.

The output of turbomachines falls off with altitude at a rate in-between that of unsupercharged and supercharged reciprocating engines. Operating at cruising speeds at a given altitude, the thrust output of turbojets is approximately independent of the flight speed, while the power output of current turboprop designs increases slowly with flight speed.

The above short summary of generally available information concerning aircraft turboengines must be augmented by the following additional observations in order to provide the background necessary for the analysis of the present paper.

TABLE 2
Values of n and K for Several Declassified Turbojet Engines

Engine	n	K at Sea Level	K	Alti-tude	K	Alti-tude
Rolls-Royce Nene I	0.83	185	170	15,000	162	30,000
General Electric I-40	0.84	195	176	25,000	174	45,000
German BMW-003	0.84	240	221	20,000	207	30,000
German Jumo-109-004-B	0.87	285	269	20,000	261	30,000

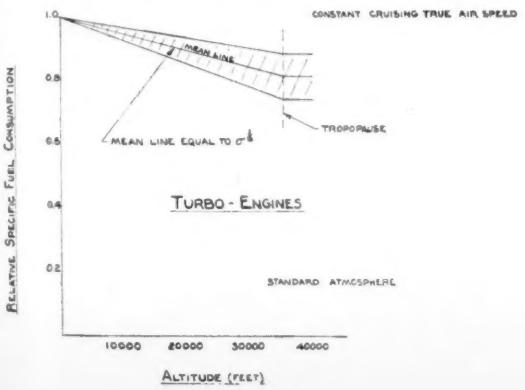
Examination of the performance *at rated r.p.m.* of about a dozen current turboengines reveals that the decrease of specific fuel consumption with altitude and flight speed may, in general, be described by the inverse power law,

$$c = K/V^n \qquad (1)$$

where K is a function of the component efficiency levels, the type of engine, and the altitude, and n is a function principally of the type of engine and the component efficiency levels. Table 2 gives values of K and n applicable to various declassified turbojet engines. A good average value for the exponent n appears to be 0.85 for current turbojet engines and about 0.1 for turboprop engines. (Note that the substitution of $n = 0$ makes Eq. (1) applicable to reciprocating engines.)

Fig. 2 shows that, for turboengines flying at a constant true speed, the minimum specific fuel consumption decreases with altitude until the tropopause, the border of the isothermal stratosphere, is reached. If the engine is of reasonable size so that the compressor and turbine operating characteristics do not suffer from significant Reynolds Number effects, the minimum specific fuel consumption is practically independent of altitude in the stratosphere, providing the combustion efficiency level is high. Fig. 3, giving the combustion efficiency as a function of altitude for several engine speeds for a Westinghouse turbojet, indicates that, when current well-developed turbojet engines operate, at rated r.p.m., the combustion efficiency level may be maintained above 90 per cent at altitudes as high as 35,000 ft. and decreases only slowly with altitude. Because of the higher design pressure ratios favored by turboprop engines, they may be expected to maintain

FIGURE 2 VARIATION OF SPECIFIC FUEL CONSUMPTION WITH ALTITUDE



their combustion efficiency at a high level up to even higher altitudes.

The fall-off of output with altitude of the average current turbomachine (see Fig. 4) may be represented by Eq. (2).

$$\begin{aligned} &\text{output} \propto \sigma^{2/3} && \text{(up to the tropopause)} \\ &\text{output} \propto \sigma && \text{(beyond the tropopause)} \end{aligned} \qquad (2)$$

While the rated thrust output of turbojets is fairly constant independent of cruising speed, the rated equivalent power output of the average current turboprop design increases approximately as the cruising speed raised to the one-fourth power (see Fig. 5).

FIG 3 - TYPICAL VARIATION OF COMBUSTOR EFFICIENCY WITH ALTITUDE

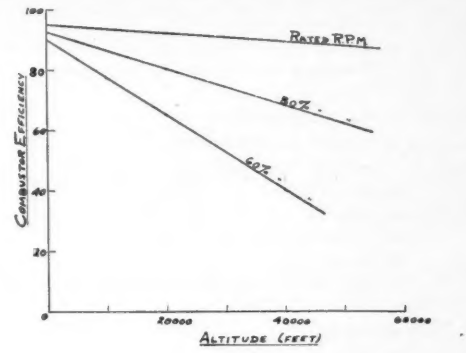


FIGURE 4 VARIATION OF ENGINE OUTPUT WITH ALTITUDE

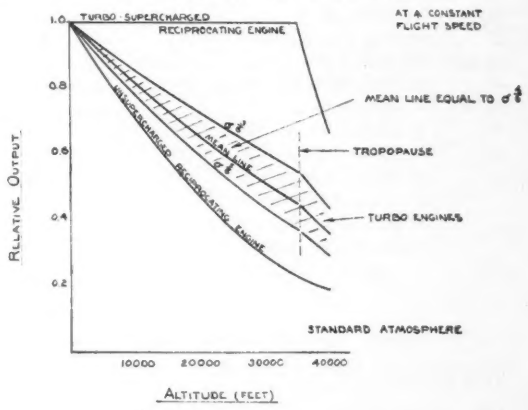
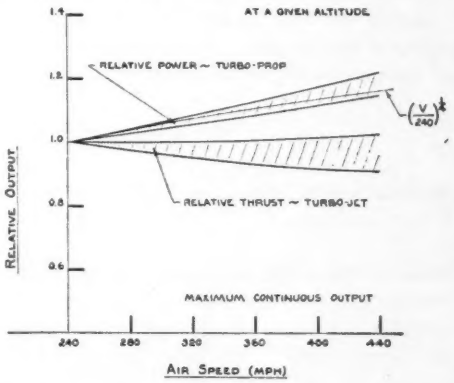


FIGURE 5 VARIATION OF RELATIVE OUTPUT WITH AIR SPEED



Symbols

A.R. = wing aspect ratio
c = specific fuel consumption—either lb. per hour per equivalent s.h.p. or lb. per hour per propulsive hp. output
C_D = total drag coefficient
C_{D_i} = induced drag coefficient
C_{D_P} = parasite drag coefficient
C_L = lift coefficient
D = drag, lbs.
e = airplane efficiency factor
F = thrust, lbs.
K = the altitude function affecting the specific fuel consumption
L = lift, lbs.
m = arbitrary constant
n = exponent
r_1, r_2, r_3 = exponents
R = range, miles
S = wing area, sq. ft.
t = time, hours
V = airplane speed, miles per hour
W = weight, lbs.
W_1 = airplane gross weight on take-off, lbs.
W_2 = airplane gross landing weight, lbs.
η_p = efficiency of propulsion—thrust power per equivalent power output
ρ = air density, slugs per cu.ft.
σ = air density relative to air density at standard sea-level conditions

Analysis

Having surveyed the principal differences between turbo- and reciprocating engines, of interest from a performance-application point of view, we are faced with the problem of weighing their relative advantages, of evaluating the significance of the lighter installed weights of turboengines as compared with their higher fuel consumptions, of determining the merits of the cleaner aerodynamic installations possible with turbomachines as compared with their unusual variation of output with altitude, etc. These comparisons can hardly be validly made without detailed application studies. However, some phases of the performance of aircraft powered by these engines may be quickly compared by means of the generalized relationships derived below.

The rate of change of weight of a plane while cruising may be expressed as:

$$dW/dt = DVc/375\ \eta_p{}^*$$

Substituting the general relation (1) for the specific fuel consumption and Eq. (3) for the cruising speed,

$$V = 0.682[W/C_L S(\rho/2)]^{1/2} \tag{3}$$

we obtain the differential Eq. (4) for the range,

$$dR = V\,dt = \frac{375(0.682)^n \eta_p C_L{}^{1-(n/2)} dW}{K C_D (S\rho/2)^{n/2} W^{1-(n/2)}} \tag{4}$$

In order to obtain the maximum increment of range at a given altitude from each drop of fuel, the cruising conditions must be such that the ratio,

$$[C_L{}^{1-(n/2)}]/C_D$$

is a maximum. It may be readily shown that this occurs when

$$[1 - (n/2)]C_{D_P} = [1 + (n/2)]C_{D_i}$$

The corresponding cruising speed is

$$V = 0.682\left[\frac{1 + (n/2)}{1 - (n/2)} \frac{W^2}{C_{D_P}\pi \text{A.R.} e (S\rho/2)^2}\right]^{1/4} \tag{5}$$

* In the case of the turbojet, the efficiency of propulsion, η_p, accounts only for the possible misalignment of the thrust and drag axes.

Substitution back into Eq. (4) and integration yields Eq. (6), defining the maximum achievable range during level flight:

$$R = 375\ (0.682)^n\ \eta_p/K \frac{[1 - (n/2)]^{(1/2)-(n/4)}[1 + (n/2)]^{(1/2)+(n/4)}(\pi \text{A.R.} e)^{(1/2)-(n/4)}}{2C_{D_p}{}^{(1/2)+(n/4)}(S\rho/2)^{n/2}(n/2)} \Big| W^{n/2} \Big|_2^1$$

$$= 375(0.682)^n \left(\frac{L}{D}\right)_{max.} \left(\frac{\eta_p}{K}\right) \frac{[1 - (n/2)]^{(1/2)-(n/4)}[1 + (n/2)]^{(1/2)+(n/4)}}{(\pi \text{A.R.} e C_{D_p})^{n/4}\ (S\rho/2)^{n/2}\ (n/2)} \Big| W^{n/2} \Big|_2^1 \tag{6}$$

which, when $n = 1$, is the approximate turbojet range formula given by Hage in reference 2 and, when $n = 0$, simplifies to Breguet's well-known range formula, Eq. (7), for reciprocating engine-powered aircraft.

$$R = 375\ [(L)/(D)_{max.}]\ [(\eta_p)/(c)]\ \log_e (W_1/W_2) \tag{7}$$

The airplane drag while on a maximum range level flight may be obtained from Eq. (8):

$$D = 2\sqrt{(W^2 C_{D_p}/\pi \text{A.R.} e)/[1 - (n/2)^2]} = 2D_p/[1 + (n/2)] = 2D_i/[1 - (n/2)] \tag{8}$$

The effect on drag and range of flying at some speed other than the best cruising speed, Eq. (5), will now be found. Assuming,

$$V = mV_{\text{best cruising}} = 0.682m\left[\frac{1 + (n/2)}{1 - (n/2)} \frac{W^2}{C_{D_p}\pi \text{A.R.} e (S\rho/2)^2}\right]^{1/4} \tag{9}$$

the corresponding airplane drag is

$$D = \left\{\frac{m^4[1 + (n/2)] + [1 - (n/2)]}{2m^2}\right\} D_{\text{best cruising}} = \frac{m^4\,[1 + (n/2)] + [1 - (n/2)]}{m^2\sqrt{1 - (n/2)^2}} \sqrt{\frac{W^2 C_{D_p}}{\pi \text{A.R.} e}} \tag{10}$$

and the range,

$$R = \frac{2m^{2+n}}{1 - (n/2) + m^4[1 + (n/2)]} R_{max.} = 375(0.682)^n \frac{\eta_p}{K} \times$$

$$\frac{m^{2+n}\,[1 - (n/2)]^{(1/2)-(n/4)}\,[1 + (n/2)]^{(1/2)+(n/4)}(\pi \text{A.R.} e)^{(1/2)-(n/4)}}{\{[1 - (n/2)] + m^4[1 + (n/2)]\} C_{D_p}{}^{(1/2)+(n/4)}\,(S\rho/2)^{n/2}(n/2)} \left| W^{n/2} \right|_2^1 \tag{11}$$

A description of the flight conditions existing at the plane's absolute ceiling may be obtained by comparing the variation of airplane drag when flying at maximum cruising speed with the variation of engine output with altitude. As may be inferred from Figs. 4 and 5, the thrust output-altitude characteristic of turboengines may, in general, be approximated by empirical power functions of the relative density of the standard atmosphere and of the flight cruising speed:

$$\text{(thrust output at altitude)/(thrust output at sea level)} = \sigma^{r_1} V^{r_2} \tag{12}$$

(the value of the exponents, r_1 and r_2, depends principally on the type of engine and on the compressibility margin built into the compressor.) Equating Eqs. (10) and (12) and solving for the conditions existing at the minimum possible value of σ, the flight speed at the absolute ceiling is found to correspond to Eq. (13).

$$m = \{[1 - (n/2)]/[1 + (n/2)]\,[1 + (r_2/2)]/[1 - (r_2/2)]\}^{1/4} \tag{13}$$

Substitution into Eq. (10) yields

$$D_{\text{absolute ceiling}} = \sqrt{\frac{1 - (n/2)^2}{1 - (r_2/2)^2}}\, D_{\text{best cruising}} = 2\sqrt{\frac{W^2 C_{D_p}/\pi \text{A.R.} e}{1 - (r_2/2)^2}} \tag{14}$$

It is seen from Eq. (6) that, when the specific fuel consumption, represented by K, does not increase rapidly with altitude, the higher the cruising altitude, the greater the level flight range. The maximum altitude at which "best cruising" conditions may be maintained is called, in this paper, the "best cruising ceiling."

The relative altitudes of the absolute ceiling and the best cruising ceiling for a given plane may be obtained from the evaluation of the relative density ratio resulting from combining Eqs. (9), (12), (13), and (14).

$$\left[\frac{\sigma_{\text{absolute ceiling}}}{\sigma_{\text{best cruise ceiling}}}\right]^{[r_1 - (r_2/2)]} = \left[\frac{1+(n/2)}{1 - (n/2)} \frac{1 - (r_2/2)}{1 + (r_2/2)}\right]^{r_2/4} \sqrt{\frac{1 - (n/2)^2}{1 - (r_2/2)^2}} \tag{15}$$

The relative range achieved at the absolute ceiling may similarly be found from Eqs. (11) and (13) as

$$\frac{R_{\text{absolute ceiling}}}{R_{\text{best cruise ceiling}}} = \left[\frac{1 - (r_2/2)}{1 - (n/2)}\right]^{(1/2)-(n/4)} \left[\frac{1 + (r_2/2)}{1 + (n/2)}\right]^{(1/2)+(n/4)} \left[\frac{\sigma_{\text{best cruise ceiling}}}{\sigma_{\text{absolute ceiling}}}\right]^{n/2} \frac{K_{\text{best cruise ceiling}}}{K_{\text{absolute ceiling}}} \tag{16}$$

So far we have been only examining cruising conditions for level range flights. Extended flights during which the airplane gross weight decreases significantly have been assumed to continue at the initial cruising altitude whether it be the initial absolute ceiling, the initial best cruising ceiling, or a lower altitude. Under certain conditions it is desirable during such flights to increase the cruising altitude as much as allowed by the decreased airplane weight. The relative range achieved during such flights may be found as Eq. (17).

$$\frac{\text{range when cruising altitude increases during flight}}{\text{range when cruising altitude remains constant}} = \left[\frac{1 - (W_2/W_1)^Y}{Y}\right]\left[\frac{n/2}{1 - (W_2/W_1)^{n/2}}\right] \Big/ \left(\frac{W_2}{W_1}\right)^Y \tag{17}$$

where the new symbols, Y and r_3, are defined by:

$$Y = \{n(1 - r_1) + 2r_3\,[1 - (r_2/2)]\}/(2r_1 - r_2)$$

and

$$K_{\text{alt}_1}/K_{\text{alt}_2} = [\sigma_{\text{alt}_1}/\sigma_{\text{alt}_2}]^{r_3}$$

Above the tropopause, Eq. (17) simplifies to Eq. (18).

$$\text{relative range} = \{(n/2)/[1 - (W_2/W_1)^{n/2}]\}\log_e (W_1/W_2) \tag{18}$$

Results and Discussion

We now have in hand a dozen or more generalized equations enabling some comparison of the performance of aircraft power plants to be made. The substitution of 0 for n leads to relationships applicable to reciprocating engine-powered aircraft—and generally well known as a result of Breguet's analysis—the substitution of $n = 0.1$, to relations applicable to turboprop aircraft; and the substitution of $n = 0.85$, to relations applicable to turbojet aircraft.

Best Cruising Speeds and Aspect Ratios

It is readily seen that, whereas reciprocating-engine-powered aircraft fly at a speed corresponding to their maximum lift-drag ratio during maximum range flight, turbopowered planes fly at a somewhat higher speed. For comparable aircraft, the best indicated cruising speeds are proportional to

$$\{[1 + (n/2)]/[1 - (n/2)]\}^{1/4}$$

(see Eq. 5). Accordingly, turbojet planes can be expected to cruise at an indicated speed at least 25 per cent greater; turboprop planes, at an indicated speed at least 2.5 per cent greater than that of conventional aircraft.

The generalized range formula, Eq. (6), shows that, whereas the maximum level flight range of reciprocating engine-powered aircraft is independent of altitude and, therefore, considering the climbing period, maximum range is achieved at sea level, the range of turbopowered planes and particularly turbojet planes increases with altitude. The practical limit to this characteristic is set by either the aircraft's service ceiling or by a rapid drop of combustion efficiency at the high altitudes reached. Because of this altitude characteristic, turbopowered aircraft may be expected to be designed for higher cruising altitudes than conventional aircraft. As a consequence, their true cruising speeds will be greater than those of reciprocating engine-powered aircraft by even more than the 25 and 2.5 per cent indicated above.

Whereas the size and weight of reciprocating engines severely restrict the speed attainable by conventional aircraft, turboprop and particularly turbojet engines are well suited to aircraft with high top speeds. In order to achieve these high speeds without severe adverse compressibility losses, wing thicknesses some 60 per cent of those common for conventional aircraft must be used. One may expect the wing aspect ratios to be reduced a corresponding amount in order to maintain a proper level for the structural weight of the aircraft. In addition, however, because of the decreased range benefits realized from a given aspect ratio when the airplane is powered by turboengines, Eq. (6), the best balance from the point of view of range between structural weight and aerodynamic drag causes a further reduction in the value of the most desirable aspect ratio to occur. This additional reduction is approximately 15 and 50 per cent for turboprop and turbojet aircraft, respectively. As compared with an optimum aspect ratio for maximum range of between 10 and 12 for conventional aircraft, high-speed turboprop planes favor an aspect ratio of about 5 or 6, and turbojet planes favor an aspect ratio of 3 or 4. As a result, their best indicated cruising speeds relative to those of reciprocating engine-powered aircraft will be higher by an additional 19 and 35 per cent, respectively. The spectrum of indicated cruising speeds for maximum range may now be tabulated as follows (airplane aerodynamic cleanliness assumed constant):

	Best Indicated Cruising Speed		
Power Plant	Optimum reciprocating engine powered plane design	Optimum medium speed plane design (thick wing)	Optimum high-speed plane design (thin wing)
Reciprocating engine	1.00	1.00	...
Turobprop	1.025	1.07	1.22
Turbojet	1.25	1.50	1.70

Relative Range and Cruising Speed as a Function of Altitude

According to Eq. (15) the air density at the absolute ceiling is lower than at the ceiling for best cruising conditions by 16 per cent for turbojet aircraft and by 10 per cent for turboprop aircraft below the tropopause, and by 10 per cent for the former and 6 per cent for the latter above the tropopause. Corresponding "absolute" and "best cruise" ceiling altitudes are tabulated below:

Absolute Ceiling, Ft.	Corresponding "Best Cruise" Ceiling	
	Turbojet aircraft, ft.	Turboprop aircraft, ft.
10,000	5,200	7,000
20,000	15,500	17,200
30,000	25,900	27,400
40,000	37,900	38,600

The possibility of flight at altitudes 2,000 to 5,000 ft. higher than the "best cruise" ceiling raises the question as to whether a greater level flight range may not be achieved by cruising at the higher ceiling altitude corresponding to a lower cruising speed. That no appreciable increase in range may be effected thereby may be surmised from the fact that the range at the absolute ceiling is about 5 per cent lower for turbojet aircraft and 9 per cent lower for turboprop aircraft than that at the lower "best cruise" ceiling [from Eq. (16)]. It may be expected, however, that it is possible to realize approximately the maximum achievable level flight range over a broad region of operating altitudes near the best cruise ceiling. Figs. 6a and 6b, showing the relative range-cruising speed-altitude picture for turbopowered planes with an absolute ceiling of 40,000 ft., confirms this expectation. (It must be remarked here that the service ceiling, which in Westinghouse application studies to date seems to be always lower than, but close to, the best cruise ceiling, actually governs the maximum level flight range when the combustor efficiency fall-off with high altitude is not dominant.)

FIGURE 6a RELATIVE RANGE AND CRUISING SPEED AT VARIOUS ALTITUDES FOR TURBO-JET PLANES

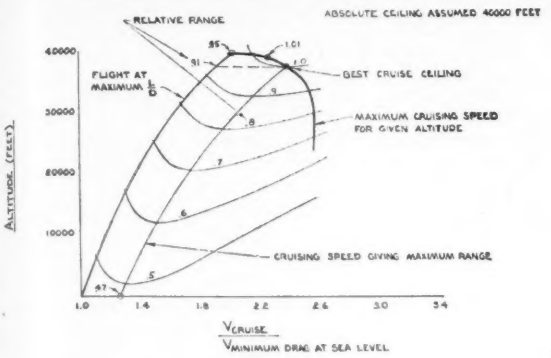

RELATIVE RANGE
ABSOLUTE CEILING ASSUMED 40000 FEET
FLIGHT AT MAXIMUM L/D
BEST CRUISE CEILING
MAXIMUM CRUISING SPEED FOR GIVEN ALTITUDE
CRUISING SPEED GIVING MAXIMUM RANGE
ALTITUDE (FEET)
VCRUISE / VMINIMUM DRAG AT SEA LEVEL

FIGURE 6b RELATIVE RANGE AND CRUISING SPEED AT VARIOUS ALTITUDES FOR TURBO-PROP PLANES

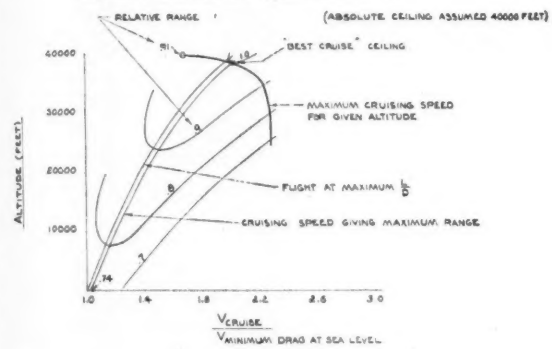

RELATIVE RANGE
(ABSOLUTE CEILING ASSUMED 40000 FEET)
"BEST CRUISE" CEILING
MAXIMUM CRUISING SPEED FOR GIVEN ALTITUDE
FLIGHT AT MAXIMUM L/D
CRUISING SPEED GIVING MAXIMUM RANGE
ALTITUDE (FEET)
VCRUISE / VMINIMUM DRAG AT SEA LEVEL

FIGURE 6c RELATIVE RANGE AND CRUISING SPEED AT VARIOUS ALTITUDES FOR RECIPROCATING ENGINE-POWERED PLANES

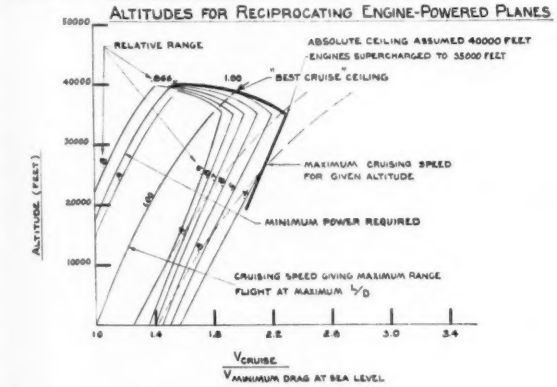
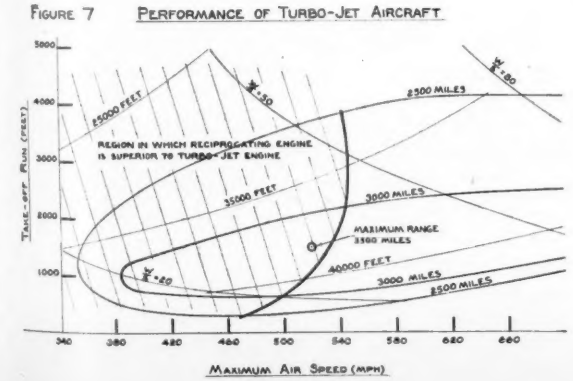

RELATIVE RANGE
ABSOLUTE CEILING ASSUMED 40000 FEET
ENGINES SUPERCHARGED TO 35000 FEET
"BEST CRUISE" CEILING
MAXIMUM CRUISING SPEED FOR GIVEN ALTITUDE
MINIMUM POWER REQUIRED
CRUISING SPEED GIVING MAXIMUM RANGE
FLIGHT AT MAXIMUM L/D
ALTITUDE (FEET)
VCRUISE / VMINIMUM DRAG AT SEA LEVEL

FIGURE 7 PERFORMANCE OF TURBO-JET AIRCRAFT



A detailed examination of Fig. 6a, showing the relative range and cruising speed at various altitudes for turbojet planes, reveals the following additional points of interest:

(a) At an altitude 1,400 ft. higher, the maximum level flight range possible is 1 per cent greater than that at the best cruise ceiling.

(b) The maximum range possible at sea level is only 47 per cent of that at the best cruise ceiling, 37,900 ft.

(c) At altitudes below the best cruise ceiling, the range achieved when flying at the maximum lift-drag ratio is 91 per cent of the maximum range possible at that altitude.

(d) At its absolute ceiling, a turbojet plane flies at its maximum lift-drag ratio.

(e) At a given altitude, the range falls off rather slowly as the cruising speed is increased beyond that corresponding to maximum range.

A similar detailed examination of Fig. 6b, showing the relative range and cruising speed at various altitudes for turboprop planes, yields these additional observations:

(a) The maximum range possible at sea level is 74 per cent of that at the best cruise ceiling, 38,600 ft.

(b) At its absolute ceiling, a turboprop plane flies at a speed 82 per cent of the speed giving the maximum lift-drag ratio.

(c) At a given altitude, the range falls off somewhat faster than for a turbojet plane as the cruising speed is increased beyond that corresponding to maximum range.

Fig. 6c showing the relative level flight range and cruising speed at various altitudes for reciprocating engine-powered aircraft turbosupercharged to 35,000 ft. has been included primarily for comparative purposes. The dashed relative range lines refer to the hypothetical level flight range if the specific fuel consumption were to remain constant independent of the engine power output; the solid relative range lines refer to the level flight range, taking into account a linear increase in specific fuel consumption to twice its minimum value as the engine power output increases from 50 to 100 per cent of normal rated power output. It is seen that, as compared with turbojet and turboprop planes, the range at a given altitude of reciprocating engine-powered aircraft falls off rapidly as the cruising speed increases beyond that yielding maximum range.

Because of the increase in range with altitude for turbopowered planes, it is sometimes desirable to fly them at increasing cruising altitudes as the fuel load is consumed and the weight of the plane lightened. The relatively greater range achieved thereby is tabulated below for several cases (combustion efficiency assumed essentially constant).

It is seen that in the case of turbojet planes appreciable gains in range are realized. In the case of turbo-

Range When Cruising Altitude Increases As the Fuel Load Is Consumed

	Range at Initial Cruising Altitude			
	—Turbojet Plane—		—Turboprop Plane—	
$\frac{W_2}{W_1}$	Below tropopause	Above tropopause	Below tropopause	Above tropopause
0.5	1.36	1.15	1.11	1.02
0.6	1.26	1.11	1.07	1.02
0.7	1.17	1.08	1.05	1.01
0.8	1.11	1.05	1.03	1.01
0.9	1.06	1.02	1.02	1.00

prop planes, however, less than one-third as much increase in range is gained when below the tropopause, while above it, the gain is negligible.

Turbojet Aircraft Performance

A rather broad application picture may be obtained from a generalized performance chart such as Fig. 7 for 60,000-lb. gross weight turbojet aircraft. It is only on the basis of the comparison of such performance charts for different types of power plants that the overall significance of the different installed power-plant weights and sizes can be evaluated and the best region of application for each power plant determined.

Fig. 7 is a typical turbojet aircraft performance chart taken from current Westinghouse application studies. (Standard methods of aircraft performance calculation have been used.) Corresponding values of wing loading, service ceiling, maximum level flight range, top speed, and length of take-off run are shown. Every point on the chart represents an airplane with a different combination of wing loading and thrust loading. Although the thrust loading has not been marked on the chart, it is indirectly indicated, for as the length of the take-off run decreases and the top speed increases, the size of the installed power plant increases. Examination of this chart enables several interesting observations to be made:

(1) The achievable range varies only slightly over a broad region of turbojet airplane design.

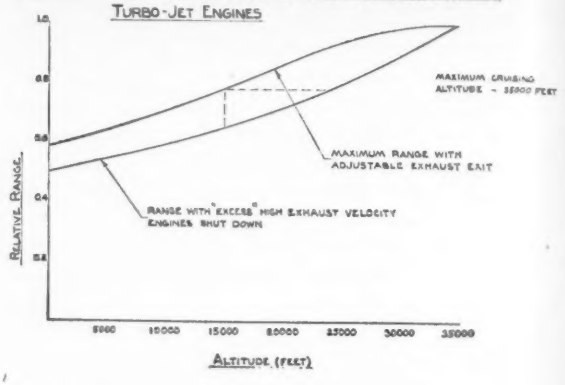
(2) Aircraft intended to have top speeds above 550 m.p.h. will achieve a greater range when powered by turbojets than when powered by reciprocating engines.

(3) Aircraft intended to have top speeds below 500 m.p.h. will achieve a greater range when powered by reciprocating engines than when powered by turbojets.

(4) There is an optimum turbojet airplane design achieving a maximum range of 3,300 miles. (Extrapolations indicate that the use of extremely large aircraft—that is, 300,000 lbs. or larger—might possibly increase this absolute range ceiling by 20 per cent to 4,000 miles.)

The performance quoted is, of course, a function of component efficiency levels achieved and may therefore be expected to improve further with the latter. Even with current efficiency levels, however, it is conceivable that for certain applications a change in the operating point of the thermodynamic cycle is to be desired. Such a change is the "derating," or operation at low turbine-inlet temperatures, of turbojet engines.[3] We have made a study of the effect on the

FIGURE 8 RELATIVE RANGE AS A FUNCTION OF ALTITUDE FOR TURBO-JET ENGINES


MAXIMUM CRUISING ALTITUDE - 35000 FEET
MAXIMUM RANGE WITH ADJUSTABLE EXHAUST EXIT
RANGE WITH "EXCESS" HIGH EXHAUST VELOCITY ENGINES SHUT DOWN
RELATIVE RANGE
ALTITUDE (FEET)

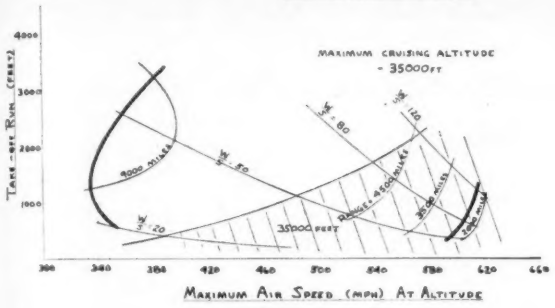
overall performance picture of the substitution of engines derated to two-thirds of their "normal" rating with a simultaneous reduction in specific fuel consumption of 25 per cent for those used in the study represented by Fig. 7. In effect, the power-plant weight was increased 50 per cent for a given thrust loading, while the reduced fuel load was consumed at a reduced rate. At high thrust loadings, W_1/F, the additional power-plant weight, and consequent reduction in fuel carried, is less than the fuel weight-saving resulting from the more economical operating specific fuel consumption, and therefore the use of "derated" engines increases the range possible; while at low thrust loadings, the reverse is true because of the relatively small amount of fuel carried, and the range is reduced. It was found, furthermore, that the maximum possible range corresponding to an optimum airplane design is increased some 5 per cent.

In the above analysis, a low exhaust velocity turbojet engine with a fixed tail area was assumed in place of the normal high exhaust velocity engine, the number of engines being increased so as to maintain essentially the same take-off run, climb, ceiling, and top speed as before. "Derating," with an accompanying improvement in specific fuel consumption, can also be effected without an increase in installed power-plant weight, while at the same time maintaining the above performance characteristics through the use of an adjustable exhaust area. With this arrangement, however, "derating" is only possible when cruising below the airplane's service ceiling.

In Fig. 8 is shown the results of a study of the benefits to be derived from "derating" with an adjustable tail area. The lower line gives the relative range of turbojet aircraft in which "excess"* engines are shut down as the cruising altitude decreases; the higher line gives the increased range effected by "derating" engines with current component efficiencies as the cruising altitude decreases. It is seen that the essential benefit derived from "derating" turbojet engines is the realization of "high-altitude" ranges at low altitudes.

* "Excess" in the sense that if all the engines were operating, they would have to run at some part-load (and, therefore, inefficient) condition.

FIGURE 9 COMPARISON OF TURBOPROP, TURBOJET, AND RECIPROCATING ENGINE POWERED AIRCRAFT



For example, the maximum range while cruising at 15,000 ft. may be increased 19 per cent. To achieve the same increase in range when using a fixed exhaust area would require the cruising altitude to be increased to 24,000 ft.

We shall bring the present paper to a close with an examination of Fig. 9, a recent Westinghouse performance application comparison of turboprop, turbojet, and reciprocating engine-powered aircraft. The maximum cruising altitude considered has been limited to 35,000 ft. The propeller efficiency has been taken as 85 per cent during cruising. (The fall-off of propeller efficiency at high flight speeds is assumed to be similar to that shown in Fig. 1.) As in the case of the turbojet aircraft performance chart of Fig. 7, every point on the chart represents an airplane with a different wing loading and power-plant loading. The range and wing-loading lines shown apply to turboprop aircraft. In the region at the extreme left of the chart (to the left of the heavy line), reciprocating engine-powered aircraft achieve a greater range than turboprop aircraft having the same top speed and length of take-off run. In the region at the extreme right of the chart (to the right of the heavy line), turbojet aircraft achieve a greater range than turboprop aircraft having the same top speed. (The take-off run, however, is always longer for turbojet planes.) In-between the two heavy lines, turboprop aircraft are superior to either turbojet or reciprocating engine-powered aircraft. It is seen that, in order for aircraft to achieve their maximum range, they should be powered by reciprocating engines when the design top speed is below 335 m.p.h.; by turbojets when the design top speed is greater than 610 m.p.h.; and, in general, by turboprops when the design top speed is in-between. Stated another way, aircraft designed for extreme ranges greater than 9,500 miles have highest top speeds when powered by reciprocating engines; aircraft designed for extreme ranges less than 2,500 miles have highest top speeds when powered by turbojet engines; while aircraft designed for an extreme range between 2,500 and 9,500 miles have highest top speeds when powered by turboprop engines.

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[2] Hage, Robert E., *A Method for Estimating Gas Turbine-Jet Airplane Performance*, A.A.F. T.R. No. 5193, March 8, 1945.

[3] Kroon, R. P., Discussion of H. Roxbee Cox's Ninth Wright Brothers Lecture, Journal of the Aeronautical Sciences, Vol. 13, No. 2, p. 86, February, 1946.

I.A.S. National Meeting Schedule

Annual Summer Meeting—Hotel Ambassador, Los Angeles—July 14–16

Wright Brothers Lecture—Washington, D.C.—December 17, 1948

Seventeenth Annual Meeting—Hotel Astor, New York, N.Y.—January 24–27, 1949

Members or organizations wishing to submit papers for presentation at National Meetings should send outlines or summaries to the Committee at least 3 months prior to the meeting.

All papers submitted will be considered for publication in the *Journal of the Aeronautical Sciences* or the *Aeronautical Engineering Review*.

All correspondence should be addressed to The Meetings Committee, Institute of the Aeronautical Sciences, 2 East 64th Street, New York 21, N.Y.

External Sound Levels of Aircraft

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EDITOR'S NOTE—*This is a condensed version of a paper presented at the I.A.S. Sixteenth Annual Meeting. The full-length paper, including 30 figures, two tables, and 27 text pages, has been published as a Sherman M. Fairchild Fund Paper and is available upon order to the I.A.S. Preprint Department.*

SUMMARY

Data were obtained concerning sound levels produced at different distances by aircraft of various sizes and engine power ratings and under take-off, climb, and cruise conditions. Sound-level readings were obtained under controlled flight conditions for six aircraft, varying from a single-engined, private-owner type of 65 hp. to a two-engined commercial type of 2,400 hp. total. Additional measurements were made with miscellaneous private, commercial, and military aircraft in the general airport traffic. Frequency analyses were made of the sound produced by the controlled aircraft.

Additional sound-level measurements were made with highway-truck and passenger-car traffic and with railway freight and passenger trains. Readings were obtained at different distances from the traffic path.

In general, the results show that the various aircraft models tested produce sound intensity levels ranging from 78 to 103 db. at a distance of 500 ft. from the airplane during take-off. With aircraft in flight, the intensity level decreases about 6.5 to 8.5 db. for each doubling of distance from the airplane.

INTRODUCTION

THE PROBLEM OF NOISE LEVELS created by aircraft in the vicinity of airports has become increasingly acute during the past several years. The importance of this problem has grown with an increasing number of private and commercial aircraft in use and, in particular, as a result of the establishment or expansion of airports in residential communities.

The complete solution of this problem ultimately must come through reduction of propeller and engine noises in aircraft if all criticism of aircraft noise is to be avoided. Airplane and propeller manufacturers are now working toward this end in cooperation with private and Governmental research organizations. However, until a solution is reached, and as an aid to such solution, a knowledge of sound levels actually existent in airport vicinities is urgently required.

The purpose of the present tests was to determine sound levels in the vicinity of airports associated with particular aircraft and comparative sound levels produced by highway and railway traffic. An additional purpose was to determine relative sound levels produced by various models of aircraft, and to obtain certain fundamental data that may be of incidental use in noise reduction design.

* Structures Section, Aircraft Development Division, Technical Development.

DEFINITION OF UNITS AND PRINCIPLES OF MEASUREMENT

The principles of sound-level measurements and properties of sound are discussed in detail in various standard texts. The present brief and elementary review of these principles is given as a guide for interpretation of the test results presented in this report.

The *sound intensity* is a measure of sound wave energy and is defined as the rate of flow of sound energy through a unit area perpendicular to a given direction at a given measuring point. Absolute sound intensity is measured in terms of watts per square centimeter.

Normally, sound intensity is more conveniently measured by the decibel scale, which expresses the existent sound intensity at a given point as a function of the ratio of the absolute sound intensity level. More exactly, the difference D in decibels between two sound intensities I_1 and I_2 is expressed by

$$D = 10 \log_{10} (I_1/I_2)$$

A standard reference level of sound intensity has been chosen as 10^{-16} watts per sq. cm., which corresponds approximately to the minimum intensity audible to the human ear at 1,000 cycles per sec.

The *intensity level* of a particular sound is the difference, in decibels, between the intensity of this sound and the intensity at the standard reference intensity level. The intensity level scale does not correspond, except in an approximate manner, to the loudness as heard by the average human ear.

Various sound intensity levels at different frequencies which appear of equal loudness to the average human ear are of equal *loudness level*. The unit of loudness level is the "phon." Standard curves showing variation of loudness level with intensity level and frequency are given in American Standards Association Standard Z24.2-1942.

Sound-level readings are, by definition, the readings given by a standard sound-level meter. It is generally desired to interpret sound-level readings in terms of loudness level. Such interpretation is complicated by the fact that normal sounds are composed of many frequency components rather than a single frequency. With selective use of three weighting networks in the sound-level meter, approximate loudness levels may be obtained by direct reading over a wide range of intensity levels and for sounds containing various frequency components.

The degree of annoyance associated with a particular sound is dependent partially upon the objective characteristics of the sound, such as its intensity, the magni-

tude of particular frequency components, the sound duration, and other factors. However, annoyance of sound also is dependent upon psychological factors that cannot readily be measured or evaluated.

The general effects of variations in atmospheric conditions upon propagation of sound have been discussed by numerous investigators.[1] It has generally been concluded that the most important atmospheric factors in this connection are local variations or gradients in the wind velocity, humidity, etc., which cause refraction and bending of sound waves through variation in the velocity of sound.

It was found during the present tests that, at the relatively short distances used (usually less than 6,000 ft.), normal variations in atmospheric conditions have little effect. At greater distances, the effects probably are much more significant.

Test Equipment

An Electrical Research Products, Inc., Type R.A.-277 Sound Frequency Analyzer and Type R.A.-246 Graphic Level Recorder were used for these tests in conjunction with a General Radio Company Type 759-B Sound Level Meter.

The sound-frequency analyzer was calibrated at the National Bureau of Standards and precise corrections were obtained. The analyzer passed frequencies of a 5-cycle band width. Both instruments were equipped with nondirectional microphones. The General Radio instrument was powered by dry batteries, while the Electrical Research Products instrument was powered in the field by a 115-volt 60-cycle a.c. portable gasoline-powered generator.

In order to prevent wind interference in the microphones, a loosely woven, open mesh "cage," 15 in. square and 18 in. high, was built around each microphone.

For the determination of the distance and altitude of passing aircraft, two transit-type sights were used. Standard telephone headsets were used to aid in simultaneous reading of each instrument.

Test Procedure

The aircraft sound-level measurements were obtained at the Weir Cook Municipal Airport at Indianapolis and at picked locations within 8 miles of the Municipal Airport which were relatively flat and open and at which relatively low normal sound levels existed. The tests were divided into two major phases: (1) controlled tests with the aircraft pilot using definite engine power settings and following specified flight paths with relation to the measuring equipment; and (2) uncontrolled tests with sound-level measurements obtained with airplanes in the general airport traffic.

The controlled tests were carried out with six aircraft.

Aircraft	Hp. Rating
Douglas C-47	2,400
Beech C-45	900
North American SNJ-4	600
Stinson 150	150
Cessna 140	85
Aeronca Champion	65

The uncontrolled tests included aircraft from 65-hp. power rating to commercial and military aircraft of about 5,700 hp. maximum.

Sound-level measurements of aircraft during take-off runs were obtained on the airport at various measured distances to the side and rear of the runway in use. One transverse cross-line along which measurements were taken was established at the starting point of the take-off run and another opposite the point at which the airplane left the ground. A longitudinal measuring line was established directly to the rear of the airplane in line with the runway.

Measurements of controlled aircraft in climbing and cruising phases of flight were obtained by placing the sound-measuring equipment at fixed locations along an isolated open road removed from the airport and flying the aircraft in an upwind direction at different altitudes across a specified point on the road. After each series of airplane passes, the measuring equipment was moved to a new location on the road, until a maximum distance of 6,000 ft. from the point of airplane crossing was reached.

Frequency analysis of the sound produced by each airplane used in the controlled tests was made with the airplane operated at approximately cruising power. During each test, an overall sound-level record was made, and separate recordings were made for the frequency band from 10 to 1,000 cycles per sec. and for the band from 100 to 10,000 cycles per sec.

Measurements of sound levels produced by highway and railway traffic were obtained with the measuring equipment placed at different distances to the side of the traffic path. The velocity of each vehicle was measured over a fixed distance, and a record was made of each individual vehicle type and model.

Test Results and Discussion

(A) Controlled Sound-Level Measurements with Douglas C-47 Airplane

The Douglas C-47 airplane used for the controlled tests was powered by two Pratt and Whitney S1C 3-G engine installations with three-bladed, constant-speed propellers. The propeller gear reduction was 0.5625, and the propeller diameter was 138 in.

The operation of the engines and airplane for the various test conditions was as follows:

	Engine			Rate of Climb, Ft. per Min.	Indicated Air Speed, M.p.h.	Propeller Tip Speed, Ft. per Sec.
	R.p.m.	Man. press., in.Hg	Hp.			
Take-off run	2,600	40	1,030	...	...	882
Climb after take-off	2,100	30	600	500	120	715
Cruise	2,000	27	550	...	150	681

The relative intensity levels in each 100-cycle frequency band for the Douglas C-47 are shown in Fig. 1. The sound intensity was concentrated principally in the 100-, 200-, and 400-cycle bands, which correspond to predominant engine and propeller frequencies. At frequencies greater than 1,700 cycles per sec., the inten-

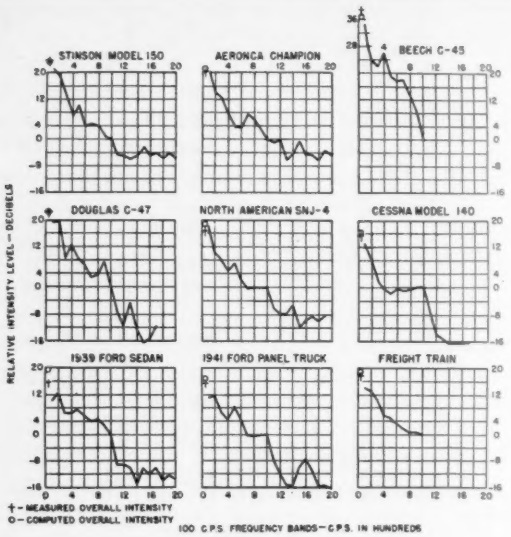

FIG. 1. Intensity levels in decibels, relative to 1,000 cycles per sec. level, for 100 cycle per sec. frequency bands of all sound sources used in controlled tests.

sity level is so low as to provide negligible contribution to the overall intensity.

Corrected intensity-level readings for take-off, climbing, and cruising conditions with the Douglas C-47 airplane are plotted against airplane-to-microphone distance in Fig. 2.

The loudness-level curves corresponding to the intensity-level curves for the climbing and cruising conditions are also shown.

The intensity-level readings obtained to the side of the airplane ground run show higher values for the shorter airplane-to-microphone distances than for corresponding distances with the airplane in either climbing or cruising flight. At the greater distances, a rapid decrease in intensity level is obtained.

These observed relationships are probably associated with reflection and attenuation effects of the ground which are not obtained in such degree after the airplane reaches an altitude of about 200 ft., and with variation in engine power settings for the take-off and climb conditions.

Data are plotted in Fig. 7 to show the variation in intensity level at various angular positions around the right side of the airplane at a constant distance of 300 ft. from a point midway between the two propeller hubs. This pattern is not necessarily symmetrical for both the right and left sides of the airplane because of the direction of rotation of the propellers, the right side of the pattern normally registering higher levels. Maximum intensity is found at an angle of 15° to 30° behind the propeller line, and a large decrease in intensity is found directly behind the airplane.

A noticeable difference was observed in the character of the sound at the side and behind the airplane, but a separate frequency analysis was not made for the latter condition. The drop in sound intensity directly behind the airplane probably is associated with the known unsymmetrical distribution of sound energy around a free propeller, coupled with a possible shielding effect of the airplane structure.[2]

(B) Controlled Sound-Level Measurements with Beech C-45 Airplane

The Beech C-45 airplane used in the controlled tests was powered by two 450-hp. Pratt and Whitney Model B5 Wasp Junior engines with direct-driven Hamilton two-bladed constant-speed propellers. The diameter of these propellers was 99 in.

The airplane and engine operating conditions for various test conditions were as follows:

	Engine			Rate of Climb, Ft. per Min.	Indicated Air Speed, M.p.h.	Propeller Tip Speed, Ft. per Sec.
	R.p.m.	Man. press., in.Hg	Hp.			
Take-off run	2,300	34	400	...	...	1,000
Climb after take-off	2,300	30	330	500	125	1,000
Cruise	1,900	26	210	...	165	821

The relative intensity levels in each 100-cycle frequency band for the Beech C-45 and other airplanes used in controlled tests are shown in Fig. 1. The greatest intensity readings were obtained in the 100-, 200-, and 400-cycle bands, similar to that shown for the Douglas C-47.

The semicircular pattern of the intensity level around the right side of the Beech C-45 airplane, at a constant

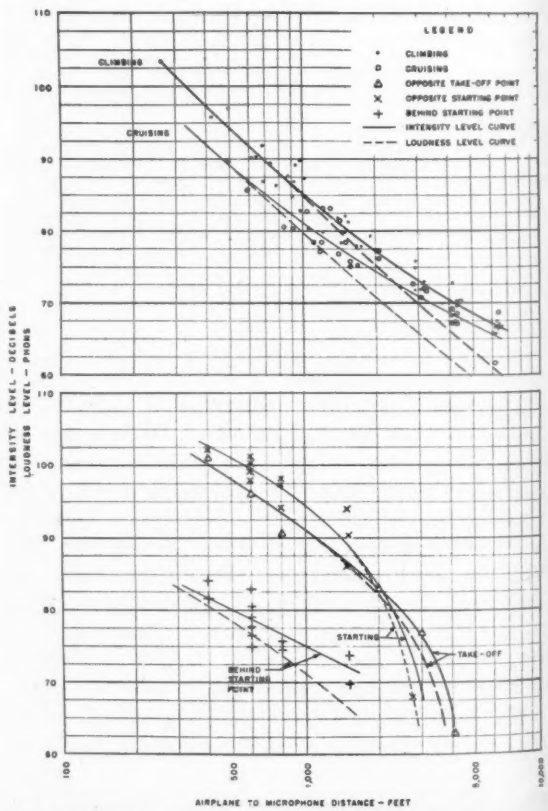

FIG. 2. Variation of intensity level and loudness level with distance for take-off, climb, and cruise conditions of Douglas C-47 airplane.

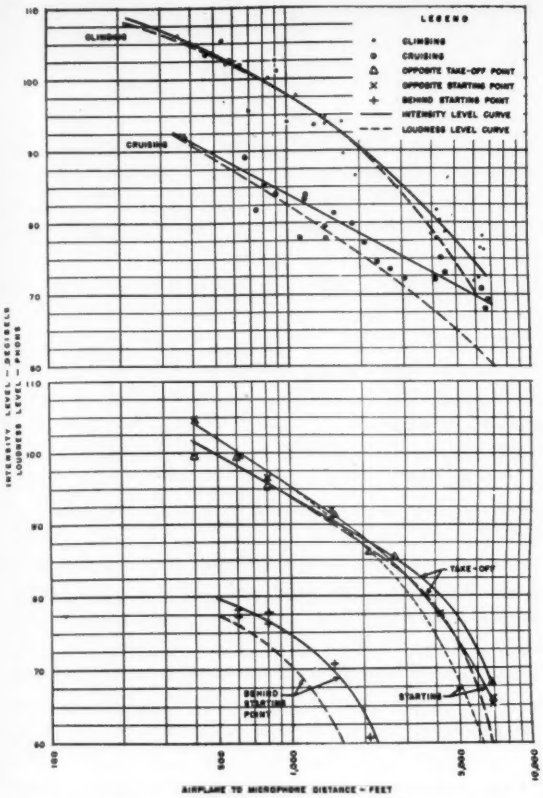

FIG. 3. Variation of intensity level and loudness level with distance for take-off, climb, and cruise conditions of North American SNJ-4 airplane.

distance of 300 ft., is shown in Fig. 7. This pattern shows that the intensity level is the greatest at an angle of 15° to 45° behind the propeller line, compared with a maximum at about 15° to 30° for the Douglas C-47.

The variation of intensity level and loudness level with distance for this airplane was found to be generally similar to that for the Douglas C-47 but with generally slightly higher levels for the Beech C-45 for equivalent distances.

(C) Controlled Sound-Level Measurements with North American SNJ-4 Airplane

The North American SNJ-4 airplane used for the controlled tests was powered by a 600-hp. Pratt and Whitney Wasp Junior engine with a direct-driven, two-bladed, constant-speed propeller of 108-in. diameter.

The airplane and engine operation data for the various test conditions were as follows:

	Engine			Rate of Climb,	Indicated Air Speed,	Propeller Tip Speed,
	R.p.m.	Man. press., in.Hg	Hp.	Ft. per Min.	M.p.h.	Ft. per Sec.
Take-off	2,300	33	600	...	...	1,084
Climb after take-off	2,300	32	580	600	125	1,084
Cruise	1,850	26	400	...	155	872

The intensity and loudness-level curves for the take-off, climbing, and cruising conditions are shown in Fig. 3. The single-engined SNJ-4 airplane has an intensity level of 108 db. during the climb for a straight-line distance of 250 ft., as compared to 102 db. intensity-level reading for the twin-engined Beech C-45 at the same distance. The loudness-level curve coincides with the intensity-level curve for measurements at distances from 650 to 1,500 ft., while at lesser and greater distances there is a gradual divergence. The slope of the curve for the cruising condition gives an approximate decrease of 5.5 db. for each doubling of distance.

Almost identical curves were obtained for the two groups of points to the side of the airplane. For the points directly behind the SNJ-4 airplane on take-off, the levels are about 20 units lower at a distance of 500 ft. than for either of the side lines and decrease rapidly for distances over 1,000 ft.

(D) Controlled Sound-Level Measurements with Stinson 150 Airplane

The Stinson 150 airplane used for the controlled tests was powered by a Franklin 150-hp. engine with two-bladed, fixed-pitch propeller. The propeller diameter was 74 in. The engine exhaust system incorporated a muffler.

The operation of the engine for the various test conditions was as follows:

	Engine		Rate of Climb,	Indicated Air Speed,	Propeller Tip Speed
	R.p.m.	Hp.	Ft. per Min.	M.p.h.	Ft. per Sec.
Take-off run	2,450	140	...	...	792
Climb after take-off	2,450	140	500	85	792
Cruise	2,300	135	...	120	743

Corrected intensity-level readings for the take-off, climbing, and cruising conditions of the Stinson 150

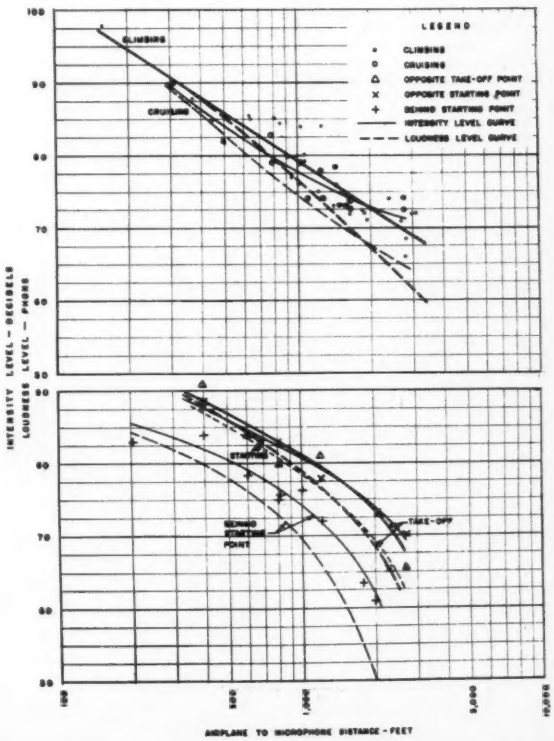

FIG. 4. Variation of intensity level and loudness level with distance for take-off, climb, and cruise conditions of Stinson 150 airplane.

airplane are shown in Fig. 4, plotted against airplane-to-microphone distance.

The intensity-level curve for the climbing condition appears to be a straight line, although some dispersion of experimental points was obtained. The corresponding curve for the cruising condition appears to curve slightly, although a straight line would provide a reasonable fit for all points except at the low intensity end. The slope of the straight line for the climbing condition corresponds to a decrease of about 6.6 db. for each doubling of distance, and the slope for the cruising condition corresponds to a decrease of about 7.0 db.

In Fig. 4 are also shown the intensity-level and loudness-level values for locations behind the aircraft starting point and to the side of the runway opposite the starting point and the take-off point. The intensity-level curves show a definite gradually decreasing slope. The intensity levels obtained for the runway side positions correspond approximately to values obtained for the climb condition for equivalent distances, but the levels behind the aircraft on take-off are lower in value.

(E) *Controlled Sound-Level Measurements with Cessna 140 Airplanes*

Controlled tests were carried out on an unmuffled Cessna Model 140 (1946) airplane. The power plant was a four-cylinder, 85-hp. Continental engine, with a 74-in., two-bladed propeller. The airplane and engine operating conditions for the various test conditions were as follows:

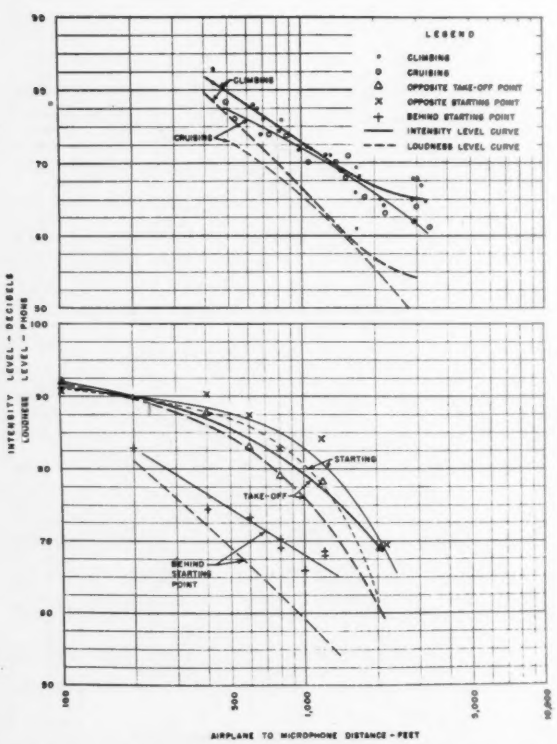

FIG. 5. Variation of intensity level and loudness level with distance for take-off, climb, and cruise conditions of Cessna 140 airplane.

	Engine R.p.m.	Engine Hp.	Rate of Climb, Ft. per Min.	Indicated Air Speed, M.p.h.	Propeller Tip Speed, Ft. per Sec.
Take-off run	2,200	75	...	...	712
Climb after take-off	2,250	76	500	75	728
Cruise	2,250	76	...	100	728

For the take-off, climb, and cruise condition, the corrected intensity-level readings and loudness-level curves for the Cessna 140 airplane are plotted against the microphone-to-airplane distance in Fig. 5. The loudness levels for these conditions are likewise shown. The intensity-level curve for the climbing condition is a straight line until the airplane-microphone distance is 1,700 ft., where the curve beings to slope upward in a manner similar to that of the Douglas C-47. Again, the reason for this is unknown, unless it can be attributed to ground effects that are not influential at the shorter distances. The slope of the straight-line portion of the intensity-level curve for the climb condition corresponds to a decrease of 6.7 db. for each doubling of distance.

The variation in intensity level at various angular directions around the right side of the Cessna 140 airplane is shown in Fig. 7. The maximum intensity level for this airplane is at an angle of 15° back from the propeller line. The levels for this airplane, however, do not vary so widely with angular direction as for the other aircraft tested.

(F) *Controlled Sound Measurements with Aeronca Champion Airplane*

The two-place Aeronca Champion airplane used in the tests was powered by a 65-hp. Continental engine with two-bladed propeller. The propeller diameter was 72 in. No exhaust muffler was incorporated.

The operation of the engine and airplane for the various test conditions was as follows:

	Engine R.p.m.	Engine Hp.	Rate of Climb, Ft. per Min.	Indicated Air Speed, M.p.h.	Propeller Tip Speed, Ft. per Sec.
Take-off run	2,300	65	...	...	723
Climb after take-off	2,300	65	400	65	723
Cruise	2,150	60	...	85	675

In Fig. 6 are shown the intensity-level data for the take-off, climbing, and cruising conditions plotted against airplane-to-microphone distance.

The average slope of the intensity-level curve for both the climbing and cruising conditions is about 6.3 db. for each doubling of distance.

With this airplane, the intensity levels measured opposite the starting point coincide closely to those obtained opposite the take-off point. The average curve for both conditions shows a decreasing slope from 100 to 400 ft. distance and a constant decrease of about 7 db. for each doubling of distance at distances greater than 400 ft. This curve falls slightly below the curve obtained for the climbing condition.

Data plotted in Fig. 7 show the variation in intensity level at different angular positions around the airplane. A maximum intensity is observed at an angle of about 15° behind the plane of the propeller.

(G) Sound-Level Measurements with Uncontrolled Aircraft in General Airport Traffic

Sound-level data were obtained with various miscellaneous aircraft during take-off and climb procedures in the general airport traffic. For each sound-level measurement, the airplane altitude and its distance from the microphone pickup were measured. All data were obtained with the aircraft on the take-off run or at relatively low altitude in the climb after take-off.

The sound-level data obtained in this manner for different aircraft are plotted against airplane-to-microphone distance in Fig. 8. Only a few measurements were obtained with certain aircraft, and considerable dispersion of points is observed with some aircraft where numerous readings were secured. Where two or more aircraft models appear to have the same average curve, the individual sets of data are combined and plotted as for one airplane.

The data obtained for the Douglas DC-3 airplane are of particular interest. Although insufficient data were obtained to provide accurate average curves and definite conclusions, a difference appears to exist between sound levels produced by airplanes of this model according to the model of engine used. The airplanes with Wright installations appear to produce intensity level values about 5 db. greater than with the Pratt and Whitney installation. This variation in level may be associated with difference in engine power used during take-off.

The slopes of the various curves shown in Fig. 8 are reasonably uniform and have an average value of about 6.0 db. drop for each doubling of distance. This aver-

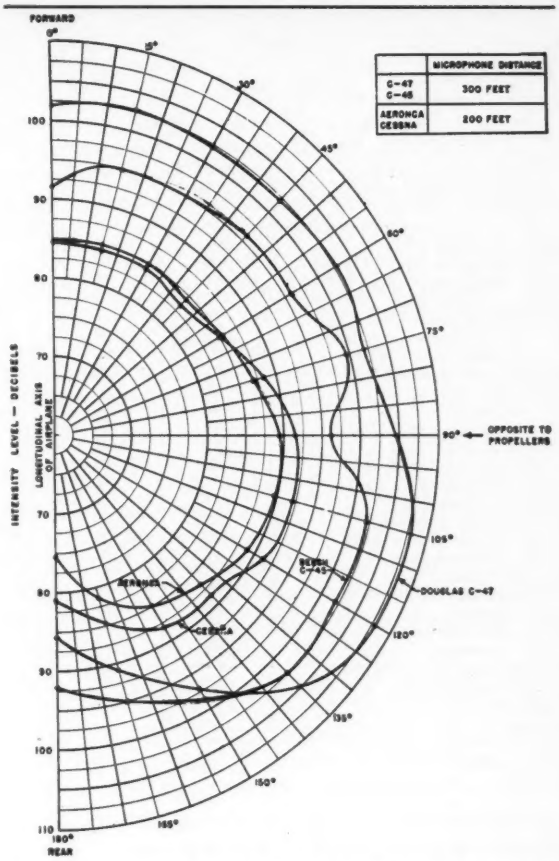

FIG. 7. Variation of intensity level with angular position around right side of four aircraft.

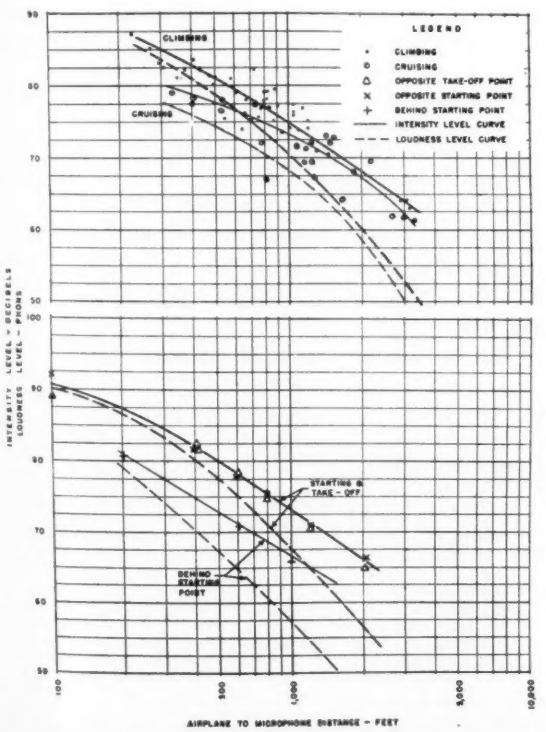

FIG. 6. Variation of intensity level and loudness level with distance for take-off, climb, and cruise conditions of Aeronca Champion airplane.

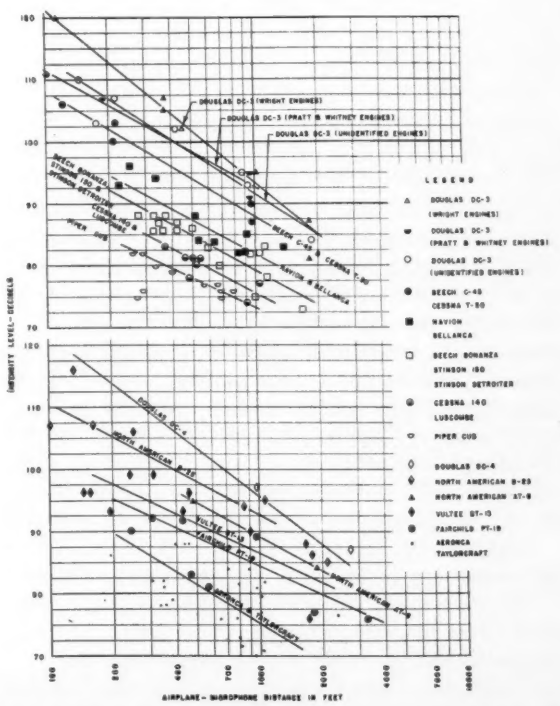

FIG. 8. Variation of intensity level with distance for take-off condition of miscellaneous aircraft in airport traffic.

TABLE 1

Comparative Sound-Level Measurements of Aircraft Recorded During Take-Off at a Distance of 500 Ft.

AIRPLANE MODEL	INTENSITY LEVEL DB	APPROXIMATE LOUDNESS LEVEL PHONS
Douglas DC-4	103	103
Douglas DC-3 (Aver.)	100	100
Douglas DC-3 (P & W)	98	98
Douglas DC-3 (Wright)	102	102
* Douglas C-47	96	96
North American B-25	98	98
North American AT-6	95	95
* North American SNJ-4	101	101
Beech C-45	94	94
* Beech C-45	94	94
Cessna T-50 (2ENG)	94	94
Vultee BT-13	91	91
Fairchild PT-19	89	88
Navion NA-145	87	86
Bellanca	87	86
Beech Bonanza	85	84
Stinson Detroiter	85	84
Stinson 150	85	84
* Stinson 150	86	85
Cessna 140	81	79
* Cessna 140	83	82
Luscombe 8A	81	79
Aeronca	81	79
* Aeronca Champion	81	79
Taylorcraft	81	79
Piper Cub	78	74

* Controlled tests.

age value is in general agreement with that obtained for the take-off condition in the controlled tests.

The military training aircraft, such as the BT-13 and the AT-6, produce a sharp and rapid pulsing sound during take-off which affects the ear strongly but which is not always distinguishable upon the sound record. The unusual effect upon the ear appears to be associated with the nature of the sound rather than its intensity.

(H) *General Discussion of Aircraft Sound-Level Data*

There are shown in Table 1 the intensity-level data for miscellaneous aircraft at a 500-ft. distance during take-off and the corresponding values for the aircraft used in the controlled tests. The values given for the controlled aircraft are the average of the values for the take-off and climb conditions. The comparison between identical aircraft in the controlled tests and the uncontrolled tests is close in most cases, the principal exception being the SNJ-4 airplane compared to the identical AT-6 airplane.

The intensity-level data given in Table 1 are plotted in Fig. 9 against the logarithm of the rated engine horsepower, or actual horsepower when known. A reasonably good straight-line relationship is obtained except for one experimental point, which represents the SNJ-4 airplane used in the controlled tests. All other points fall within 3.5 db. of the average curve shown.

The plotted points are distinguished in Fig. 9 according to propeller tip speed but not according to other factors that are known to influence intensity of generated sound. However, no consistent effect of propeller tip speed is observable in the plotted data.

It may possibly be concluded from Fig. 9 that in most normal aircraft design the different factors affecting sound production vary together in such manner as to maintain a simple relationship between sound intensity produced and size of the power plants. The total engine power apparently is the predominant factor.

Five of the aircraft listed in Table 1, with intensity levels also plotted in Fig. 9, utilized engine exhaust mufflers. These aircraft were the North American Navion, Beech Bonanza, Stinson 150, Bellanca, and the Piper Cub. No significant difference in sound level generally is noted between the muffled and unmuffled aircraft. It may be concluded that engine exhaust muffling alone has little effect upon sound intensity, since sound intensities of equal or greater value normally are produced by the propeller.[2]

The duration of aircraft sound is difficult to express, since the sound level is continually changing, and the shape of the sound level vs. time curve varies with distance from the airplane and with airplane velocity. In general, the duration of aircraft sound above a 70-phon loudness level and at distances from the aircraft less than 1,000 ft. varies from 10 to 30 sec.

(I) *Sound-Level Measurements with Highway and Railway Traffic*

The data plotted in Fig. 10 include both passenger and freight trains pulled by steam locomotives and traveling at different velocities. No systematic variation was noted for type or speed of train. The slope of the curve given for variation of intensity level with distance for locomotives whistling and the slope of the curve found for normal train sounds are similar in value. However, the intensity levels of locomotives whistling are approximately 10 db. greater for identical distances than for trains alone. The nature of the curves obtained is similar to that obtained with aircraft on the ground and probably is similarly explained by ground effects. If comparison is made of the railway train intensity level to the intensity level produced by aircraft at a similar distance, it is found that the train traffic produces about the same level as small aircraft types and locomotive

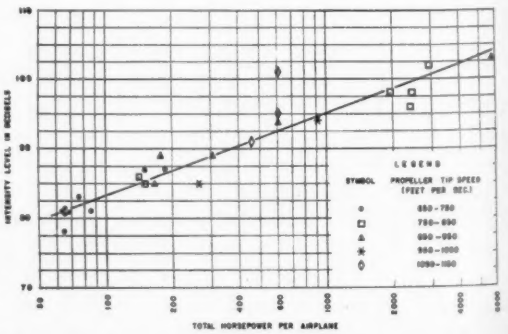

FIG. 9. Variation of intensity level with total engine power and propeller tip speed for take-off of all measured aircraft at 500-ft. distance.

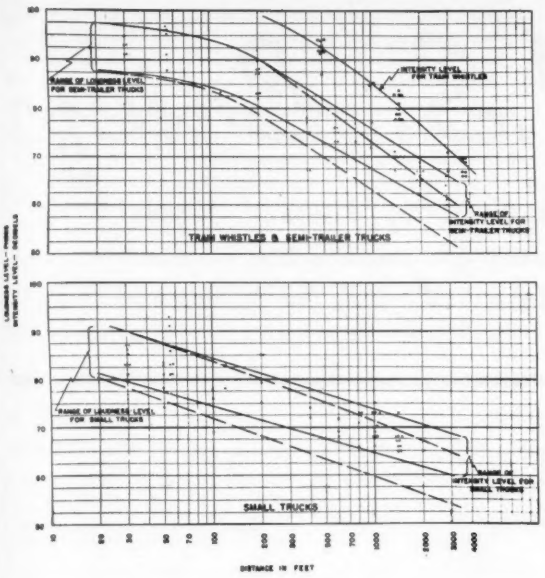

FIG. 10. Variation of sound level with distance for highway-truck traffic accelerating or climbing hills and for railway train whistles.

whistles produce about the same level as a twin-engined aircraft.

The variation in individual readings for highway traffic sound levels is large. Such variation appears to be dependent upon differences in individual vehicles of each general class and to some extent upon the velocity of travel. However, only a general tendency could be seen for increase of sound intensity with vehicle velocity, and no specific separation of points could be made.

If the maximum curves only are considered, it is observed that a shape and slope generally similar to that found with aircraft is obtained. The slope is of such value as to cause a 3.0- to 3.5-db. decrease in intensity for each doubling of distance.

A definite difference in sound levels produced by the different classes of trucks and the passenger cars was observed. For the cruising condition, the smaller trucks produce loudness levels about 4 phons less than the large semitrailer trucks, and the passenger cars produce levels about 7 phons less than the large trucks.

Semitrailer trucks climbing or accelerating in low gear produce sound-intensity levels 4 to 15 db. greater than for the land cruise condition, and the corresponding increase for small trucks is 1.5 to 11.5 db. The average values are increased approximately 10 and 4.5 db., respectively.

The duration of highway traffic loudness levels in cruise condition above the 70-phon level is about 4 sec. for passenger cars and about 10 to 20 sec. for trucks, at a distance of 100 ft. For railway traffic, the duration varies greatly with length and velocity of train. The duration of loudness levels of trucks climbing hills is considerably greater than the above figures because of the lower velocity of the vehicle.

CONCLUSIONS

(1) The sound intensity associated with conventional aircraft is dependent principally upon the total power being delivered by the aircraft engine or engines. Propeller tip speed is known to influence substantially the level of sound produced, and it has been shown by other investigators that low tip speeds, in combination with intensive exhaust muffling, will result in greatly decreased sound intensity. The number of propeller blades, the propeller tip clearance, the airplane velocity, and other factors are also known to influence the sound level produced. It may be concluded from the present data that, in conventional aircraft with no exhaust muffling and with moderate variation in propeller tip speed and other factors that influence sound production, no systematic effect of these miscellaneous variables can be readily observed, and the sound level associated with the aircraft is determined principally by the delivered engine power.

(2) The intensity level of aircraft noise, at a distance of 500 ft. from the airplane during take-off, varies from about 78 db. for small aircraft to 103 db. for the Douglas DC-4 airplane.

(3) Airplane sound intensity level varies approximately inversely as a power of the distance from the airplane. For most aircraft, this relationship is such as to cause a 6.0 to 8.5 decrease in intensity level for each doubling of distance.

(4) The effect of the ground upon the rate of decrease of sound intensity with distance is not observable when the airplane altitude is greater than 200 ft. With lower aircraft altitude and with the airplane on the ground during the take-off run, the sound apparently is re-enforced by ground reflections at short distances and is rapidly attenuated by ground effects at greater distances.

(5) The intensity level directly behind the airplane during the ground take-off run is relatively low in magnitude and is attenuated rapidly with distance.

(6) The effect of engine exhaust mufflers upon sound intensity of aircraft appears to be small.

(7) Automotive highway traffic produces sound intensity levels that vary widely for individual vehicles. Maximum intensity level for semitrailer trucks in cruising condition is about 89 db. at a 50-ft. distance, and 78 db. at a 400-ft. distance. Maximum values for lighter trucks in cruising condition are about 4 db. less and for passenger cars are about 7 db. less. Maximum intensity levels for semitrailer trucks climbing is about 96 db. at a 50-ft. distance and 84 db. at a 400-ft. distance. Maximum values for lighter trucks in climbing condition are about 8 db. less.

(8) Railway traffic produces sound intensity levels of about 96 db. at 50-ft. distance and 84 db. at 400-ft. distance. No consistent variation was noted between passenger and freight trains or between trains at different velocity. Locomotive whistles produce sound intensity levels of about 94 db. at a 400-ft. distance.

(*Continued on page 51*)

I.A.S. Briefs

Summaries of current papers accepted for publication or presentation at I.A.S. Meetings

Theoretical Pressure Distributions for a Thin Airfoil Oscillating in Incompressible Flow

By

E. E. Postel and E. L. Leppert, Jr.

Lockheed Aircraft Corporation

Formulas are derived for the theoretical pressures acting on a thin airfoil and aileron combination oscillating with harmonic motion of small amplitude in incompressible flow.

Calculations of pressure distribution are made at several representative values of the frequency parameter $1/k$ for airfoil translation, for airfoil rotation about the quarter-chord, and for hinged-surface flapping motions. The tabulated data thus obtained are plotted.

These formulas and curves make possible a comparison with experimentally determined pressures which can point the way to empirical modification of the two-dimensional coefficients and may make possible a modification of theory. Of equal importance is the possibility of comparing three-dimensional experimentally determined pressures with present strip-theory methods of estimating three-dimensional effects. Development of instrumentation has progressed sufficiently to indicate that pressure measurements are feasible. Direct measurement of pressures eliminates many of the difficulties of force measurements, such as the correction of test data for structural damping, inertia, and stiffness forces.

Recent N.A.C.A. Research on High-Length-Beam Ratio Hulls*

By

Arthur W. Carter

Langley Memorial Aeronautical Laboratory, N.A.C.A.

A series of related seaplane hulls having a wide variation in length-beam ratio have been investigated by the Langley Laboratory of the N.A.C.A. An increase in hull length-beam ratio from 6 to 15, holding the length-beam product constant, reduced the aerodynamic drag without appreciably affecting the hydrodynamic qualities in smooth water, reduced the vertical accelerations and motions during landings in rough water, and reduced the structural weight required for a given load factor.

Extreme warping of the forebody planing bottom of length-beam ratio 15 resulted in large reductions in the landing accelerations and considerably improved the spray at low speeds. Warping the forebody and lengthening the afterbody resulted in further reductions in the maximum vertical and angular accelerations.

The high-length-beam ratio hull, which has been shown to have acceptable hydrodynamic characteristics, is therefore of particular interest in the design of high-performance water-based aircraft, inasmuch as appreciable reductions in aerodynamic drag and hull weight may be obtained. Such high length-beam ratios combined with long afterbodies and warped forebodies are markedly superior to conventional length-beam ratios for rough-water operation.

* Paper to be presented at the Annual Summer Meeting, I.A.S., Los Angeles, July 14–16, 1948.

Please do not order Preprints of these papers at this time.

See page 52 for Preprints that are immediately available.

Deep Ring Analysis

By

Kuang Sheng Ching

Chinese Air Force

A paper with the title of "Calculation of the Stresses in Annular Frames" by H. Fahlbusch and W. Wegner was published in the November, 1941, issue of the Journal of the Royal Aeronautical Society. It deals with the depth effect insofar as the neutral axis of the ring is offset from the skin line, but no consideration is given to curvature (the distribution of stress due to bending being as for a straight beam) or to the deformation due to direct load and shear force.

In the present paper the curved-beam theory and also the direct and shear deformations have been taken into consideration. The result obtained agrees with the above-mentioned paper in the region of small ratio of depth to outside radius but differs considerably when the depth-radius ratio is large.

The Aerodynamic Forces on an Oscillating Flap at Supersonic Speeds

By

John W. Miles

University of California

Using the general results developed in an earlier paper, the complex flutter coefficients A_{bh} (hinge moment due to plung-

ing), $A_{b\alpha}$ (hinge moment due to pitching), $A_{c\beta}$ (lift due to flapping), $A_{a\beta}$ (pitching moment coefficient due to flapping), and $A_{c\beta}$ (hinge moment coefficient due to flapping) are found. All of these coefficients are expressed in terms of the previously known coefficients $A_{a\alpha}$, A_{ah}, $A_{c\alpha}$, and A_{ch}. Numerical results are given in the form of curves for $M = 1.2$, 1.4, 1.6, and 2.0, the real and imaginary parts of the coefficients being plotted vs. k for a range of $k = 0$ to 1.4. In the case of $A_{a\beta}$, $A_{b\beta}$, and $A_{c\beta}$ the results are applicable to any flap, while the numerical results for $A_{b\alpha}$ and A_{bh} are given for 25 and 50 per cent chord flaps.

Inlet Conditions of Centrifugal Compressors for Aircraft Engine Superchargers and Gas Turbines

By

H. Woodhouse

Test results indicate that the angle of attack becomes critical for relative inlet velocities in excess of 1,400 ft. per sec. for air and at comparable Mach Numbers for the various freons and that the optimum positive angle of attack is approximately 4°.

The curves shown indicate that, particularly for low inlet temperatures, the increase in inlet velocity due to change of density becomes marked for approach velocities in excess of 400 ft. per sec.

Hyperbolic Column Formulas for Magnesium-Alloy Extrusions

By

E. H. Schuette

The Dow Chemical Company

Results are presented for tests of 89 Z-section columns of M, FS-1, J-1, 0-1, and 0-1HTA alloys. The tests were conducted in an effort to arrive at suitable column formulas for use in design.

The following supplementary conclusions were reached:

(1) The tangent modulus column curve does not give consistently good fits to test data for magnesium-alloy extrusions.

(2) The end fixity achieved by a column tested flat-ended is probably influenced by the cross-sectional shape of the column.

(3) Rounds and shapes follow qualitatively different column curves.

Stability of Boundary Layers and of Flow in Entrance Section of a Channel

By

Elizabeth Hahneman, J. C. Freeman, and M. Finston

Brown University

Lin's approximate formula for the minimum critical Reynolds Number is used to study the entrance flow into a channel, the boundary layer with pressure gradient, and the boundary layer with suction. It is found that the results thus obtained compare favorably with much more elaborate calculations wherever they are available. In the case of the entrance flow into a channel, the new result is found that the entrance section is comparatively more stable than the fully developed parabolic velocity distribution.

On Airfoil Theory and Experiment

By

Alan Pope

Georgia School of Technology

The more exact equation for the slope of the lift curve is restated, and a relation for the location of the aerodynamic center is advanced. An approximate method for determining the minimum drag coefficient and extent of the low drag bucket is also given.

Transient Loading of Airfoils at Supersonic Speeds

By

John W. Miles

University of California

Using the results for the pressure distribution over a supersonic airfoil due to a harmonic velocity distribution and the Fourier integrals for step and impulse functions, the pressure distribution and lift and moment coefficients have been calculated for the uniform entry of a flat plate into a sharp-edged gust and for the sudden deflection of a flap, the latter including the sudden pitching of the entire airfoil as a special case. Results are given in the form of algebraic equations plus curves for C_L and C_M for $M = 1, 2^1/_2, 2, 4$, and ∞.

External Sound Levels of Aircraft

(*Continued from page 49*)

(9) Automotive and aircraft sound sources have all principal frequency components with significant energy at frequencies of 500 cycles per sec. or less.

(10) Normal variations in wind velocity, relative humidity, cloud conditions, and other atmospheric factors apparently have little effect upon propagation of sound at distances less than about 1 mile. At greater distances, atmospheric variations probably have much larger effect.

(11) Effect of variation in terrain is important in connection with sound propagation. In general, obstacles such as hills, buildings, or foliage directly between the observer and the sound source may have some attenuating or shadowing effect. Such obstacles to the side or rear of the observer may have a strengthening effect because of sound reflections. However, no generally applicable quantitative corrections can be made for such conditions.

REFERENCES

[1] Lord Rayleigh, *Theory of Sound*, Vols. 1 and 2.

[2] Theodorsen, Theodore, and Regier, Arthur A., *The Problem of Noise Reduction with Reference to Light Airplanes*, N.A.C.A. T.N. No. 1145.

I.A.S. Preprints

Preprints of Meeting Papers Currently Available

No.

107 The Testing of Rotors for Fatigue Life—Jonathan Winson, Consultant, Prewitt Aircraft Company

109 Chordwise and Beamwise Natural Frequencies of Rotor Blades—Gabriel Horvay, Engineering General Division, General Electric Company

110 The Helicopter Control Rotor—Joseph Stuart, III, Project Engineer, United Helicopters, Incorporated

117 N.A.C.A. Investigation of Gas-Turbine Blade Cooling—H. Ellerbrock, Flight Propulsion Research Laboratory, N.A.C.A.

118 Problems of Gas-Turbine Propeller Combinations—Frank W. Davis, Assistant Chief Engineer, Consolidated Vultee Aircraft Corporation

119 The Automatic C-54—James Anast, All-Weather Flying Division, Air Materiel Command

121 Loss Prevention Programs in Aviation—J. C. Lederer, Chief Engineer, Aero Insurance Underwriters

122 A Study of Wing De-Icer Performance on Mount Washington—D. L. Loughborough, H. E. Greene, and P. A. Roush, Physical Research Laboratory, The B. F. Goodrich Company

123 Dynamic Lateral Stability As Influenced by Mass Distribution—Leonard Sternfield and Marion O. McKinney, Jr., Stability Research Division, Langley Memorial Aeronautical Laboratory, N.A.C.A.

124 A Critical Study of Aircraft Landing Gears—J. F. McBrearty, Division Engineer, Lockheed Aircraft Corporation

125 Inert Gas Installation—H. W. Naulty, Cornell Aeronautical Laboratory

130 The Boundary Layer of Yawed Infinite Wings—J. M. Wild, Graduate School of Aeronautical Engineering, Cornell University

131 Linearized Theory of Supersonic Control Surfaces—P. A. Lagerstrom, Assistant Professor, Guggenheim Aeronautical Laboratory, California Institute of Technology, and Martha E. Graham, Douglas Aircraft Company, Inc.

133 A Wing Body Problem in a Supersonic Conical Flow—S. H. Browne, L. Friedman, I. Hodes, Aerophysics Laboratory, North American Aviation, Inc.

No.

134 The Transient Reaction of a Two-Dimensional Wing at Supersonic Speed Due to Change in Angle of Attack—Chieh-Chien Chang, Associate Professor, Department of Aeronautics, The Johns Hopkins University

135 Prediction of Load Distribution and Its Effect on Aerodynamics Characteristics at Subsonic Speeds for Wings of Arbitrary Plan Form—Victor Stevens, Ames Aeronautical Laboratory, N.A.C.A.

137 Experimental Study of Cooling by Injection of a Fluid Through a Porous Material—Pol Duwez and H. L. Wheeler, Jr., Jet Propulsion Laboratory, California Institute of Technology

138 The Flow of a Perfect Fluid Through an Axial Turbomachine with Prescribed Blade Loading—Frank E. Marble, National Research Council Predoctoral Fellow, Guggenheim Aeronautical Laboratory, California Institute of Technology

139 Service Experience with Turbojets—J. W. Bailey, Head, Engineering Services, Allison Division, General Motors Corporation

140 An Evaluation of Engine Design Compromises—Neil Burgess, Aircraft Gas Turbine Division, General Electric Company

141 Layout and Preliminary Design Problems—Milton U. Clauser, Chief, Mechanics Section, Douglas Aircraft Company, Inc.

142 Air Inlets and Nacelles—William J. Blatz, Project Aerodynamicist, McDonnell Aircraft Corporation

143 Tailpipe, Nozzle, and Jets—Herbert C. Towle, Jr., Principal Thermodynamicist, Republic Aviation Corporation

144 Accessory Equipment in Turbojet Installations—F. H. Sharp, Assistant Project Engineer, Consolidated Vultee Aircraft Corporation

145 The Four-Stroke Spark Ignition Compound Engine—LeRoy V. Humble and Cecile G. Martin, N.A.C.A.

146 The Two-Stroke Compression Ignition Compound Engine—Arnold E. Biermann and Max J. Tauschek, N.A.C.A.

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148 The Turbojet Engine—Reece V. Hensley and Newell D. Sanders, N.A.C.A.

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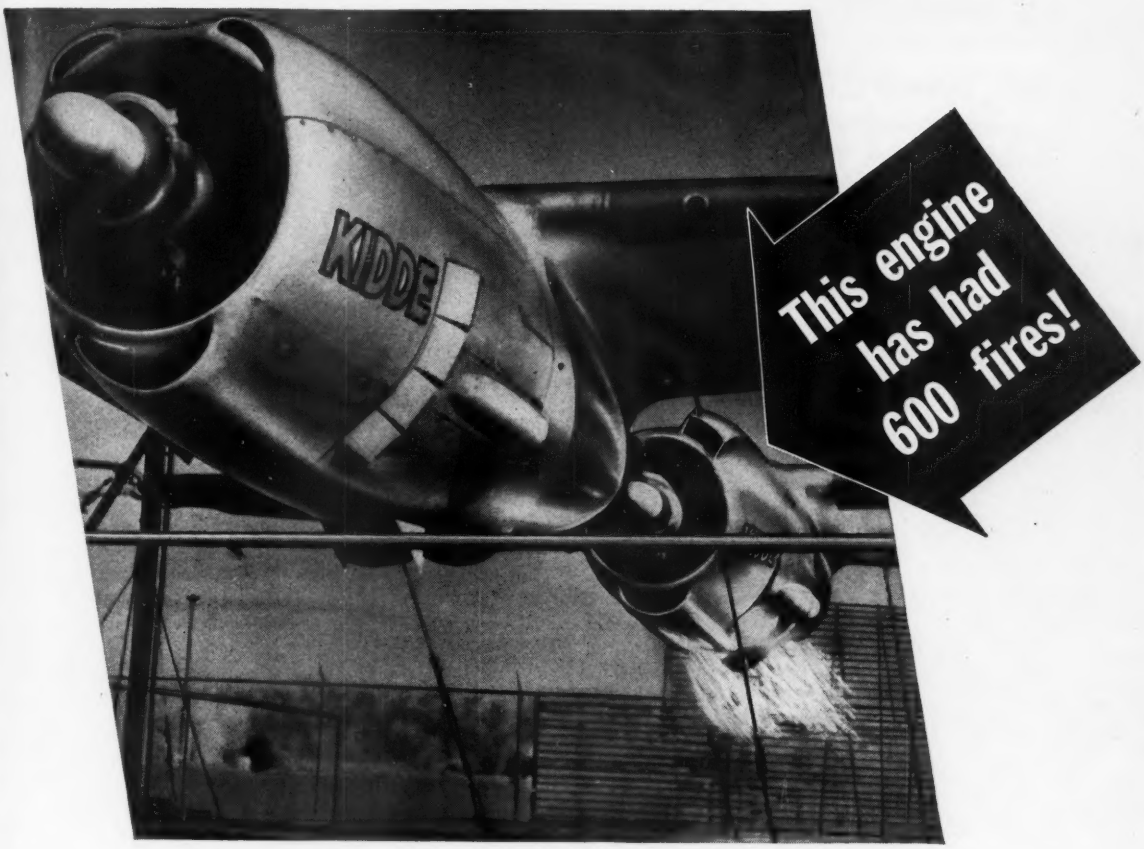

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The abstracts are classified according to the Standard Aeronautical Indexing System. Numbers in parentheses indicate the position of the Division Headings in the numerical arrangement. Headings marked by an asterisk have not yet been established by the S.A.I.S.

Aerodynamics (2) 56
Boundary Layer 56
Control Surfaces 56
Fluid Mechanics & Aerodynamic Theory 57
Internal Flow 57
Parasitic Components & Interference 57
Wings & Airfoils 57
Airports & Airways (39) 58
Air Power (43) 58
Airplane Design & Description (10) 58
Aviation Medicine (19) 60
Electronics (3) 60
Engineering Practices & Aids (49) 60
Equipment
Electrical (16) 60
Flight Testing (13) 60
Fuels & Lubricants (12) 60
Gliders & Gliding (35) 63
Guided Missiles (1) 63
Hydrodynamics (21) 63
Installations
Underground (32) 63
Instruments (9) 63
Laws & Regulations (44) 65
Maintenance (25) 65
Management & Finance (45) 65
Materials (8)
Metals & Alloys 65
Nonmetallic Materials 67
Sandwich Materials 67
Meteorology (30) 67
Operations
Commercial (41) 69
Photography (26) 69
Power Plants
Jet & Turbine (5) 71
Reciprocating (6) 71
Production (36) 73
Propellers (11) 73
Rotating Wing Aircraft (34) 73
Safety & Rescue (15) 74
Sciences, General (33)
Mechanics 74
Stress Analysis & Structures (7) 74
Wind Tunnels & Laboratories* 75

II. BOOKS REVIEWED IN THIS ISSUE

Photoelasticity, Vol. 2. Max. M. Frocht 77
Reviewed by F. S. Shaw, Brown University

Aerodynamics of the Oscillating Airfoil in Compressible Flow. S. N. Karp, S. S. Shu, and H. Weil 77
Reviewed by Dr. Paul Lieber, Polytechnic Institute of Brooklyn

Personal Aircraft Business at Airports. Lynn L. Bollinger and Arthur H. Tully, Jr. 78
Reviewed by Maurice H. Smith, I.A.S.

The Failure of Metals by Fatigue. Symposium Held in the University of Melbourne 78

Book Notes 81

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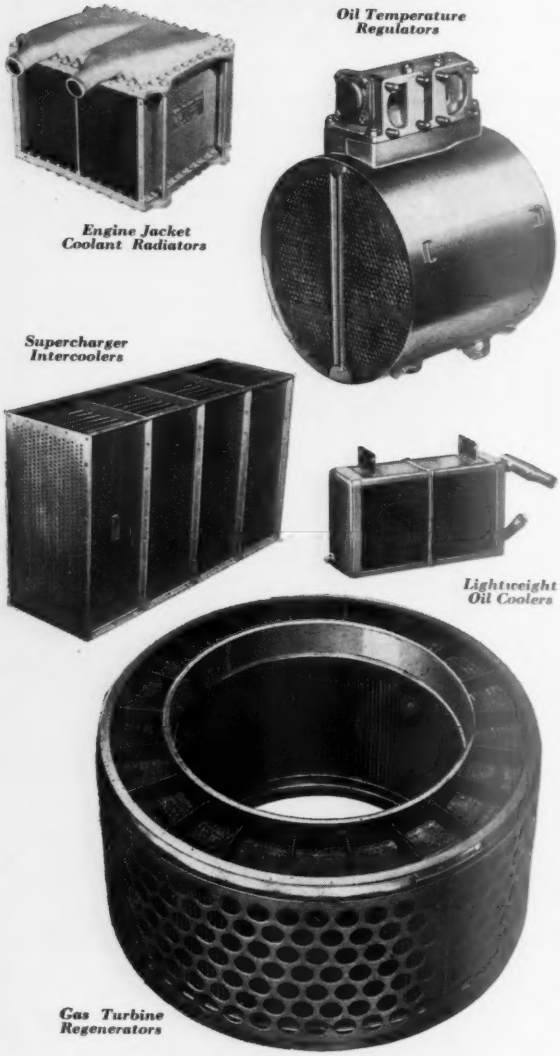

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Aerodynamics (2)

BOUNDARY LAYER

The Laminar Boundary-Layer Equations. I—Motion of an Elliptic and Circular Cylinders. II—Integration of Non-Linear Ordinary Differential Equations. D. Meksyn. *Royal Society of London, Proceedings, Series A*, Vol. 192, No. 1031, March 18, 1948, pp. 536–575, figs., tables. 27 references.

I. The general two-dimensional equation of motion is derived for the boundary layer at a boundary with radii of curvature which are not very small and about which the potential flow is known. For the front part of a cylinder, the equation is reduced to a form that is the same as that studied by Flakner and Skan. This equation is used to compute the pressure and velocity of the boundary layer on an elliptic and on a circular cylinder under the same conditions that pertained in the experimental determinations made by Schubauer and by Fage and Falkner. The general equation is used to calculate the separation point. For the elliptic cylinder the calculated and observed velocities agree for a distance from the forward stagnation point along the boundary of the ellipse equal to 1.457 times the length of the minor axis. The stagnation point is found to be at about 108° 30′ from the separation point measured in elliptic coordinates. The observed stagnation point was 103°. In the case of the circular cylinder the calculated surface friction agrees well with the measurements.

II. The mathematical work involved in obtaining the particular integrals required in the preceding section. The operations are performed on both the general and the restricted equation of motion, thus obtaining particular integrals of nonlinear differential equations that satisfy specified boundary conditions and tend exponentially to zero at infinity.

An Air-Injection Method of Fixing Transition From Laminar to Turbulent Flow in a Boundary Layer. A. Fage and R. F. Sargent. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2106*, June, 1944. 8 pp., diagrs., figs. 9 references. British Information Services, New York. $0.70.

In order to introduce into the flow at each test speed the minimum disturbance necessary to fix transition from laminar to turbulent flow small air jets with an adjustable rate of injection are blown into the boundary layer at the desired position. Experiments to establish the effectiveness of this technique show that the minimum rate of air injection required to produce transition is only 0.015 times the rate of mass-flow in the boundary layer. The method is especially suitable for high-speed tests since it does not give a local shock wave such as is sometimes present when a surface wire is used.

Free Streamline Suction Slots. E. J. Watson. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2177*, February, 1946. 25 pp., figs. 5 references. British Information Service, New York. $1.45.

The theory of free streamlines, even though it is based on potential flow and is not strictly applicable to boundary-layer suction slots, is used to design such slots or similar entries to ducts. These slots may be compared with those derived empirically by Fage and Sargent, except that, in general, they have a step between the flat boundaries at either side of the slot. A series of slots covering a range of slot angles and of ratios of stream velocity to slot velocity are illustrated. The formulas by which they are calculated are collected in the appendix.

CONTROL SURFACES

Application of the Linearized Theory of Supersonic Flow to the Estimation of Control-Surface Characteristics. Charles W. Frick. *U.S., N.A.C.A., Technical Note No. 1554*, March, 1948. 56 pp., diagrs. 2 references.

In order to obtain estimates of the hinge moment and effectiveness characteristics of elevators and ailerons, the conical-flow solutions of the linearized equation for the velocity potential in supersonic flow are applied to the calculation of the characteristics of control surfaces. Complete solutions for the pressure distributions are obtained for control surfaces the trailing edges of which are swept ahead of the Mach line. Approximate solutions of good accuracy are obtained for those cases in which the trailing edge is swept behind the Mach line.

The Effect of Brake Flaps on an Aerofoil at High Speeds. I—Measurements on the Effect of Brake Flaps on an Aerofoil at High Speeds. A. E. Knowler and F. W. Pruden. **II—Further Wind-Tunnel Tests of Brake Flaps at High Speeds.** F. W. Pru-

den. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2211*, June, 1942. 23 pp., illus., diagrs. 3 references. British Information Services, New York. $1.45.

I. Measurements of the effect of brake flaps of various shapes and sizes on the lift, drag, and pitching moment of an airfoil. It was found that in general, from the aerodynamic point of view, the best position for the flaps was at the trailing edge.

II. To determine the stressing of air brakes and wing covering, pressure measurements were made around a two-dimensional double split-flap combination airfoil, on the brake flaps themselves, and in the wake in the vicinity of the tail. The measured pressure coefficients displayed a sudden increase in the vicinity of Mach 0.75.

FLUID MECHANICS & AERODYNAMIC THEORY

On Free Boundaries of an Ideal Fluid. I—The Principle of Analytical Continuation. Max Shiffman. *Communications on Applied Mathematics*, Vol. 1, No. 1, January, 1948, pp. 89–99, diagrs.

A method of determining the free boundaries of an ideal two-dimensional flow in which the actual physical plane of the flow is dealt with. The principle of reflection across free boundaries is used in which the analytic function describing the flow across the free boundary is extended to obtain an image of the actual flow and the boundaries and singularities of the image are determined. By this method the problem is reduced to one involving fixed walls alone and can be solved by a conformal mapping without the necessity of an additional integration that is required in treatments derived from the basic procedure of Helmholtz.

INTERNAL FLOW

Theoretical Considerations Concerning the Flow Pattern in a Two-Dimensional Diffuser (Project No. HA-219). G. Guderley. *U.S., Air Force, Technical Report No. F-TR-1174-ND (GS-USAF Wright-Patterson Air Force Base No. 80)*, March, 1948. 14 pp., diagrs. 6 references.

The method used in this study of the mixed supersonic-subsonic flow patterns in a two-dimensional diffuser considers the physical and the hodograph planes simultaneously. The restrictions to which mapping in the hodograph plane is subject enforces a well-defined structure upon the flow pattern in both the hodograph and the physical plane. A series of figures gives a continuous sequence of theoretical flow patterns such as would occur as the width of the narrowest cross section of the diffuser was changed from zero to a value at which sonic velocity was established in the diffuser throat. Comparison of these theoretical results with schlieren photographs reveal a number of discrepancies some of which may be caused by deviations from the two-dimensional flow.

PARASITIC COMPONENTS & INTERFERENCE

Wind-Tunnel Investigation of Carburetor-Air Scoops for the XTB2D-1 Airplane With Emphasis on Means for Bypassing the Boundary Layer. Mark R. Nichols, Arvid L. Keith, and Robert W. Boswinkle. *U.S., N.A.C.A., Memorandum Report (Wartime Report No. L-751)*, June, 1944. 112 pp., illus., diagrs. 3 references.

WINGS & AIRFOILS

Prediction of Load Distribution and Its Effect on Aerodynamic Characteristics at Subsonic Speeds for Wings of Arbitrary Plan Form. Victor I. Stevens. *Aeronautical Engineering Review*, Vol. 7, No. 6, June, 1948, pp. 37–42, diagrs. 2 references.

A comparison of the theoretical methods of Falkner, Weissinger, and Mutterperl for predicting the loading of wings shows that Falkner's method gives the least deviation from experimental results but that Weissinger's method is sufficiently accurate and considerably less time-consuming than the other two. The Weissinger method was used to calculate the aerodynamic characteristics of about 200 wings, whose general range of variables included sweep of from 45° forward to 60° back, aspect ratios of 1.5 to 8.0, and taper ratios of 0 to 1.5. On highly tapered wings, sweepback was found to move the aerodynamic center aft and sweepforward to move it forward. The magnitude of this movement was generally increased by increase in aspect ratio. On sweptback wings, tapering the wing to a more pointed plan form increased the lift-curve slope, whereas on swept-forward wings, inverse taper produced a similar increase in the lift-curve slope. On highly swept wings the taper ratio exerted as great an influence on the lift-curve slope as the aspect ratio. Although these results apply only to incompressible flow, application of the Prandtl-Glauert rule should make it possible to predict accurately the effects of compressibility and thus obtain an estimation of the effects of Mach Number on wings flying at speeds below the critical speed.

The Aerodynamic Derivatives with Respect to Sideslip for a Delta Wing with a Small Dihedral at Supersonic Speeds. A. Robinson and J. H. Hunter-Tod. *College of Aeronautics, Cranfield, England, Report No. 12*, December, 1947. 24 pp., diagrs. 2 references.

Expressions are derived for the sideslip derivatives on the assumptions of the linearized theory of flow. When the leading edges are within the Mach cone from the apex, the pressure distribution and the rolling moment are independent of the aspect ratio. There is also a leading edge suction that is a function of incidence, aspect ratio, and Mach Number which contributes as well as the surface pressure distribution to the side force and yawing moment. When the leading edges are outside the apex Mach cone, the nondimensional rolling derivative is, in contrast to the other case, dependent on Mach Number and independent of aspect ratio. The other derivatives and the pressure, however, are dependent on both variables. There is no leading edge suction force in this case. In the appendix a transformation is derived that links, under conditions of conical flow, the method of Stewart and that of Robinson for solving the problem of the lift at supersonic speeds of a flat delta wing lying within its apex Mach cone.

Low Aspect Ratio Rectangular Wings in Supersonic Flow. P. A. Lagerstrom and Martha E. Graham. *Douglas Aircraft Company, Inc., Report No. SM-13110*, December, 1947. 29 pp., figs. 9 references.

Linearized theory and the superposition of mixed-type wings is used to investigate the aerodynamic characteristics of airfoils with rectilinear plan forms. A formula, in closed form, which is obtained for the chordwise location of the center of pressure, shows that when the effective aspect ratio is reduced from 1 to $1/2$, the location of the center of pressure shifts from 33 per cent chord to 1.5 per cent chord from the leading edge. This rapid shift of the center of pressure as the Mach Number approaches 1 emphasizes the inadequacy of the linearizing assumptions. A qualitative description, therefore, is given of the flow over a rectangular wing. The intersection of conical compression and expansion waves show that the nonlinear corrections to the center of pressure locations are more important than like corrections to the lift and drag values. An expression is also obtained in closed form for the variation in the coefficient of lift with the angle of attack. The appendixes give detail calculations of the lift and center of pressure of a mixed-type wing, the lift of a rectangular wing, and the center of pressure of a rectangular wing.

The Theoretical Lift of Flat Swept-Back Wings at Supersonic Speeds. Doris Cohen. *U.S., N.A.C.A., Technical Note No. 1555*, March, 1948. 77 pp., figs. 13 references.

A practical method for approximating the theoretical lift distribution of the conventional sweptback wing. The method used is the superposition of linearized conical flows. The wings are assumed to be thin, flat, and at an angle of attack in a supersonic flow considerably greater than Mach 1. The various plan forms are distinguished by the sweep of the leading and trailing edges relative to their respective Mach lines. Where the Mach line from the apex of the wing lies behind the leading edge but intersects the tip, formulas for the total lift are given in closed form. The induced drag is simply the lift multiplied by the angle of attack, and the pitching moment is obtained by the numerical integration of elementary functions. Where the leading edge alone is swept behind the Mach lines, both the pressure distribution and the total lift are given in closed form, but not the pitching moment. The induced drag can be calculated directly from the lift. It is not possible, except by a series of successive approximations, to obtain by this method a complete solution for the case of highly swept wings with both leading and trailing edges behind their respective Mach lines. The pressure distribution, however, can be determined over all but the region in which the tip and trailing edge Mach cones overlap. The total lift, pitching moment, and induced drag can be approximated with practical accuracy as long as the Mach lines from the trailing edge do not intersect the leading edge. An investigation is also made of the case in which the

tips of a wing are normal to the stream. The method is illustrated by calculating this wing and two conventional sweptback wings with 63° sweep of the leading edge at a Mach Number of 1.5.

The Damping Due to Roll of Triangular, Trapezoidal, and Related Plan Forms In Supersonic Flow. Arthur L. Jones and Alberta Alksne. *U.S., N.A.C.A., Technical Note No. 1548,* March, 1948. 23 pp., diagrs. 3 references.

The surface integral method was used to obtain the linearized-potential-theory load distribution due to roll in supersonic flow of triangular plan forms with subsonic leading edges and with supersonic leading edges; trapezoidal plan forms with all possible combinations of raked in, raked out, subsonic or supersonic tips; rectangular plan forms; and two sweptback plan forms developed from the triangular wings. These load distributions were integrated to determine the rolling moment and the damping-in-roll stability derivatives and the results wave plotted as curves of the variation of the damping-in-roll coefficient with the aspect ratio parameter. All but the sweptback plan forms and the triangular plan forms with subsonic leading edges were investigated with the leading edges and trailing edges reversed relative to the stream direction. It was found that while this changed completely the distribution of the load, it had no effect on the value of the damping-in-roll stability derivative.

Free Oscillations of an Aerofoil About the Half-Chord Axis at High Incidences, and Pitching Moment Derivatives for Decaying Oscillations. J. B. Bratt, K. C. Wight, and A. Chinneck. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2214,* September, 1940. 14 pp., diagrs., tables. 2 references. British Information Services, New York. $1.15.

An investigation to determine the conditions that give rise to sustained or growing oscillations of an airfoil free to perform pitching oscillations about the half-chord axis. The tests were concerned with the variation of the additional deflection with the mean incidence required to give this type of oscillation. The effect of change of frequency parameter and Reynolds Number are given in the form of stability diagrams. The method used to analyze the photographic records of the test data eliminated the effect of solid friction in the mechanical system.

Airports & Airways (39)

Traffic Control Requirements for Jet Transport Aircraft. Warren T. Dickinson. *Shell Aviation News,* No. 116, February, 1948, pp. 14–19, diagrs.

A comparison of the performance characteristics of a DC-6 with those of a four-engined jet transport shows that the high sensitivity of jet aircraft to optimum operating conditions will require traffic control to be effective to altitudes as high as 40,000 ft. The control system facilities will have to be spaced laterally and longitudinally to provide sufficient airspace for maneuvering at high speeds. The fuel consumption characteristics of jet aircraft prohibit holding and stacking and require the assignment of landing positions or diversion to alternate destinations prior to descent from the optimum operating altitude. The airport will have to be able to accommodate extremely high descent speeds and ground running time and taxiing.

Plan Boost in Air Traffic Control. Robert B. Hotz. *Aviation Week,* Vol. 48, No. 12, March 22, 1948, pp. 25, 26, diagrs.

A summary of the interim 5-year program proposed by the Radio Technical Commission for Aeronautics, Special Committee No. 31, to increase the efficiency of the Federal airways system. The target plan that proposes the accommodation of 100,000 aircraft by 1963 will consist principally in the installation and development of all-weather flying aids. A brief description is given of the navigation equipment, landing systems, traffic-control systems, and communications that have been specified.

The Jan Smuts Project; First Stages in the Construction of South Africa's Class "A" Airport (Johannesburg). *Airports & Air Transportation,* Vol. 2, No. 58, March, 1948, pp. 327–333, illus.

Thin-Skinned Airports; Thinner Runway Surfaces Proved in Studies by Canadian Experts. *Canadian Aviation,* Vol. 21, No. 3, March, 1948, pp. 24, 25, illus.

Fix Up Those Lights. Leslie C. Vipond. *Aviation Maintenance & Operations,* Vol. 9, No. 4, March, 1948, pp. 34, 35, illus. Practical tips on the inspection and maintenance of airport lighting systems.

Air Power (43)

The Present and Future of the Aircraft Industry. Claude N. Monson. *Mechnical Engineering,* Vol. 70, No. 3, March, 1948, pp. 211, 212, 216.

Our Vanishing Airmada: What Has Happened to the Wartime Air Force of 80,000 First-Line Airplanes? John A. Giles. *Ordnance,* Vol. 32, No. 167, March-April, 1948, pp. 306–308, illus.

Airplane Design & Description (10)

The Problem of the Personal Aeroplane. W. Nichols. *Aeronautics,* Vol. 18, No. 4, March, 1948, pp. 34–39, diagrs.

Expansion of the light aircraft market appears to depend on offering the public a design that will minimize pilot's errors and incorporate the maximum in safety features. Analysis of accident statistics shows that the most important of these include a simplification of control systems by reducing the number of independent motions required of the pilot, an increased field of vision from the cabin, and an improvement of the stalling characteristics. A design is proposed for a "light ideal" aircraft that incorporates these features. This is two-passenger, pusher, low-wing, twin-rudder monoplane, powered by a 110-hp. flat 4-cylinder Jameson engine located low in the fuselage and driving the propeller through a drive shaft. The air frame is of plywood sandwich construction with a light-alloy tail boom. General layout and profile drawing, airflow pattern, and diagrams of landing characteristics are included.

Freighter Aircraft. I. H. W. Ainsley. *Airports & Air Transportation,* Vol. 2, No. 58, March, 1948, pp. 337, 338.

The Snow Characteristics of Aircraft Skis. George J. Klein. *Canada, National Research Council, Aeronautical Report No. A R-2 (N.R.C. 1496, MM 57),* 1947. 17 pp., illus. 5 references.

Measurements were made on approximately half-scale model skis of various shapes, surfaced with various materials. Tests over a large range of temperature and snow conditions and over a large range of unit loadings showed that highly loaded skis, surfaced with bakelite and with comparatively high aspect ratio and small bow angle, were much superior to skis of conventional design. A theory of ski resistance is proposed which agrees well with the results of the tests.

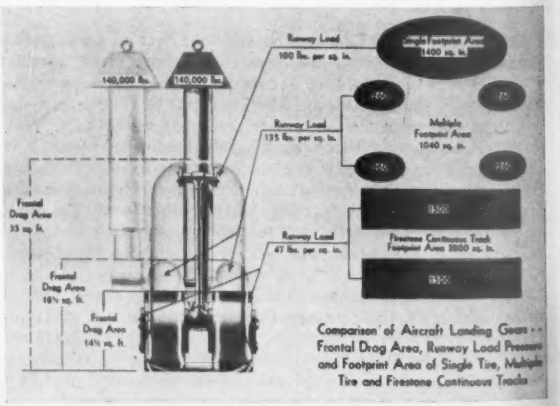
Landing Gear Designed to Give Softer Let-Down. *Aviation Week,* Vol. 48, No. 12, March 22, 1948, p. 27, diagr.

"Siflex," the landing gear now used on the Luscombe two-place Silvaire, comprises a flexible tubular steel leg with a combination coil spring oleo unit. This combination has the simplicity of a spring type of gear and the light weight and shock absorbing qualities of an oleo gear.

High Speed Viking (Vickers-Armstrong). John Portway. *Aeronautics,* Vol. 18, No. 4, March, 1948, p. 49.

Towards the Foolproof Aeroplane (Winter Zaunkönig). R. G. Worcester. *The Aeroplane,* Vol. 74, No. 1918, March 12, 1948, pp. 307–310, illus.

Performance characteristics of the Zaunkönig from German publications and from English tests. Observation of tufts on the upper wing surface of this high-wing parasol monoplane shows that it is impossible to stall the aircraft. Simplicity of take-off and landing characteristics suggest that this craft might be used for flight instruction without dual controls.



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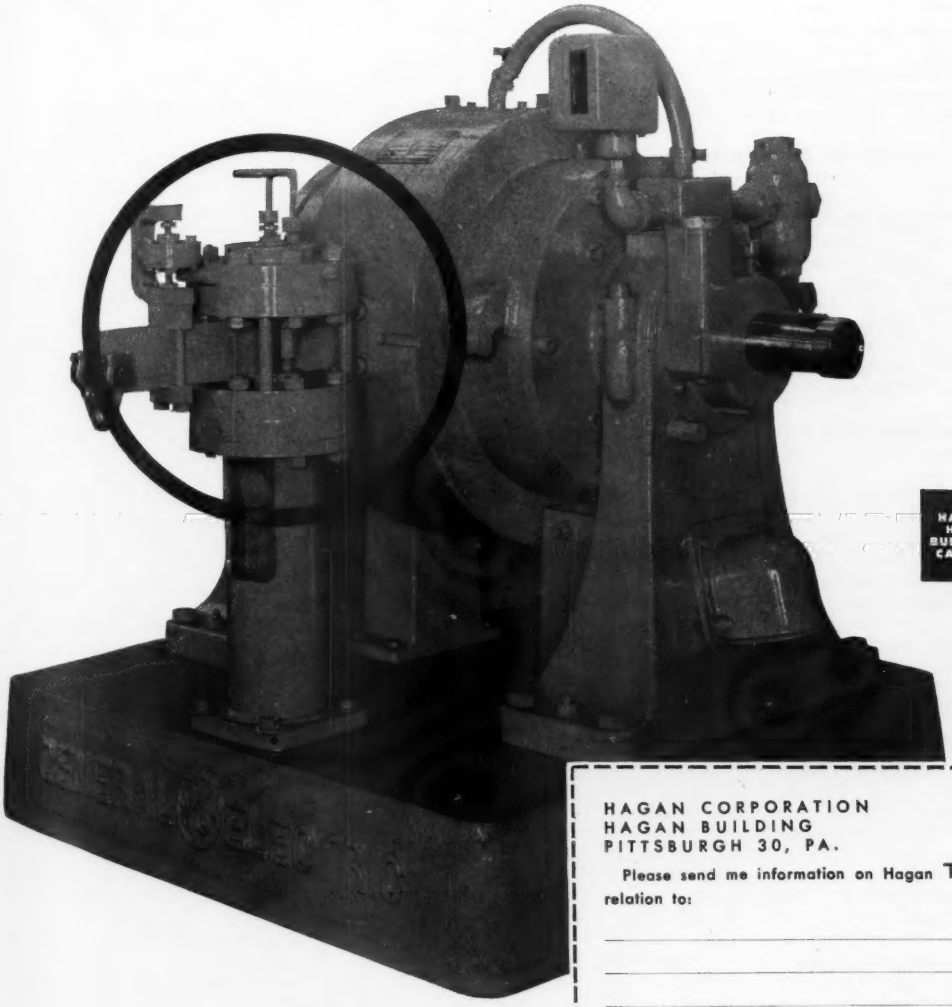

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Aviation Medicine (19)

Of What Importance are Psychological Factors in Motion Sickness? G. R. Wendt. *Journal of Aviation Medicine*, Vol. 19, No. 1, February, 1948, pp. 24–33. 19 references.

The results of a series of experiments conducted by the author in which 597 subjects were exposed to wave motion with various wave duration, form, acceleration level, and energy level per wave; and an analysis of research literature on motion sickness. Indications are that physical and physiological factors are practically more important than psychological factors in causing motion sickness.

Distance Discrimination. VI—The Relationship of Visual Acuity to Distance Discrimination. Monroe J. Hirsch and Frank W. Weymouth. *Journal of Aviation Medicine*, Vol. 19, No. 1, February, 1948, pp. 56–58, fig. 5 references.

The correlation coefficient (0.73) obtained between visual acuity and distance acuity of 315 subjects and the effect of illumination on distance discrimination thresholds and on visual acuity indicate that visual acuity and distance discrimination depend on the same visual capacity, namely, the form sense and, probably, specifically on brightness determination.

Application of Human Engineering to Flight Problems. Leonard C. Mead. *Journal of Aviation Medicine*, Vol. 19, No. 1, February, 1948, pp. 45–51. 9 references.

A summary of the design principles used in a biotechnological approach to the engineering of aircraft instrument displays, control levers and devices, and the layout of aircraft equipment. Includes an outline of the research program of the Human Engineering Section of the Special Devices Center of the Office of Naval Research.

Psychological Research at the AAF School of Aviation Medicine. Merril Roff. *Journal of Aviation Medicine*, Vol. 19, No. 1, February, 1948, pp. 20–23.

Human Tolerance to Negative Acceleration of Short Duration. Robert S. Shaw. *Journal of Aviation Medicine*, Vol. 19, No. 1, February, 1948, pp. 39–44, illus. 5 references.

Experiments to determine human tolerance to forces such as those experienced in escape from aircraft by downward seat ejection. For periods of time less than 0.3 sec. accelerations higher than 3 negative *g* can be tolerated.

Aero Medical Program in the Army Air Forces. Malcolm C. Grow. *Journal of Aviation Medicine*, Vol. 19, No. 1, February, 1948, pp. 52–55, 60.

Training for Voice Communication at High Altitudes. John W. Black. *Journal of Aviation Medicine*, Vol. 19, No. 1, February, 1948, pp. 34–38, tables.

Development of Aircraft Oxygen Equipment by the USAF. F. W. Berner and D. R. Good. *Journal of Aviation Medicine*, Vol. 19, No. 1, February, 1948, pp. 2–11, illus., diagrs.

The design and the functioning of equipment proposed and in current use in aircraft oxygen-supply systems. Portable and airborne oxygen-producing units, the Bendix converter to transform liquid oxygen into gaseous oxygen, standard and experimental regulators, and face gear are under development.

The Nominating Technique as a Method of Evaluating Air Group Morale. John G. Jenkins. *Journal of Aviation Medicine*, Vol. 19, No. 1, February, 1948, pp. 12–19, fig.

Electronics (3)

Ultrasonic Delay Lines. II. A. G. Emslie, H. B. Huntington, H. Shapiro, and A. E. Benfield. *Franklin Institute, Journal*, Vol. 245, No. 2, February, 1948, pp. 101–115, illus. 4 references. (Cf. AER 5/48:48.)

A discussion of the properties of delay lines employing a liquid medium and an outline of research and development. The properties of the transmitting medium, carrier frequency, reflectors, and mechanical tolerance required are the factors that determine the selection of the transmitting medium and the dimensions of the delay line. The overall size of the unit can be reduced by using reflecting surfaces and bending the path of the signal back upon itself or by using a tank, the walls of which reflect the beam. Transit attenuation, range of carrier frequencies, operating frequencies of the crystals, crystal dimensions, and the elimination of accessory signals are treated. The design of delay lines is illustrated by a detailed description of the mechanical construction, assembly technique, and fitting details of a laboratory model for delays of the order of 500 microsec., at a carrier frequency of 15 Mc., and a production model designed for 3,300 microsec. delay.

Air-Borne Radar. R. W. Ayer. *Electrical Engineering*, Vol. 67, No. 3, March, 1948, pp. 246–248, illus. (Extended summary of a paper.) Brief summary of recent developments in air-borne radar which provide collision and storm warning, navigation aids, and ground-speed indication.

Engineering Practices & Aids (49)

New Method of Producing Three-Dimensional Plaster Models. John S. Haldeman. *Machinery*, Vol. 54, No. 7, March, 1948, pp. 144–149, illus.

Racks of adjustable pikes are supported in a frame. The height of the pikes is adjusted at the drafting table to conform to the contour of a given cross section of the model. The racks of pikes are set at the proper stations in the frame and covered with a wire mesh upon which the plaster model is built. By shaving and scraping the model to conform to the indentations of the points of the pikes, a plaster model is built directly without the use of templates.

Equipment

ELECTRICAL (16)

Electricity Aloft. Thomas J. Martin. *Electrical Engineering*, Vol. 67, No. 3, March, 1948, pp. 232–235, illus. A general discussion of aircraft electrical systems including sources of power for generators and alternators, engine-speed controllers, and voltage regulators.

The Hysteresis Motor. Herbert C. Roters. *Electrical Engineering*, Vol. 67, No. 3, March, 1948, pp. 241–245, illus. (Extended summary of a paper.)

Design description and performance analysis of a hysteresis motor that develops one-quarter horsepower with an efficiency of 80 per cent. The use of a distributively wound stator with short air gaps minimizes the hysteresis losses in the rotor and those that remain occur at low excitation.

Aircraft Searchlights. F. D. Stebbins. *Aviation Maintenance & Operations*, Vol. 9, No. 4, March, 1948, pp. 42, 71, illus. Design, operation, and control of an aircraft searchlight for illuminating ground objects.

Flight Testing (13)

High Speed Flight Research; Its Value in Determining Compressibility Effects on Drag, Lift, Stability and Control. H. Davies. *Flight*, Vol. 53, No. 2048, March 25, 1948, pp. 332, 333, figs. (Summary of a paper.)

Because of the difficulty of reproducing all the conditions of high-speed flight in wind tunnels, it has been necessary to dive-test piloted aircraft. In these tests, records of the pressure pattern on the test section showed the relation that the shock wave and the boundary layer bore to the change in the slope of the drag curve. The effects of compressibility on lift and of compressibility buffeting have also been investigated.

Fuels & Lubricants (12)

Japanese Fuels and Lubricants: Research on Rocket Fuels of the Hydrogen Peroxide-Hydrazine Type. *Gt. Brit., British Intelligence Objectives Sub-Committee, Report No. B.I.O.S./J.A.-P./P.R./826*, February, 1946. 112 pp., illus., diagrs. 5 references. British Information Services, New York. $3.25.

Reports by Japanese personnel on the rocket-fuel research program at the Japanese First Naval Fuel Depot. This project, to develop fuel for the Shusuk aircraft and the Kaiten torpedo, included laboratory studies on the manufacture, stabilization, and storage of concentrated (80 per cent) hydrogen peroxide solutions, laboratory and pilot plant studies of the synthesis of hydrazine, the design and operation of hydrogen peroxide concentration plants, and combustion studies of the peroxide-hydrazine mixture.

The Knock-Limited Performance of Fuel Blends Containing Aeromatics. V—*n*-Propylbenzene, *n*-Butylbenzene, Isobutylbenzene, *m*-Xylene, and 1-Isopropyl-4-Methylbenzene. Carl L. Meyer and J. Robert Branstetter. *U.S., N.A.C.A., Advance*

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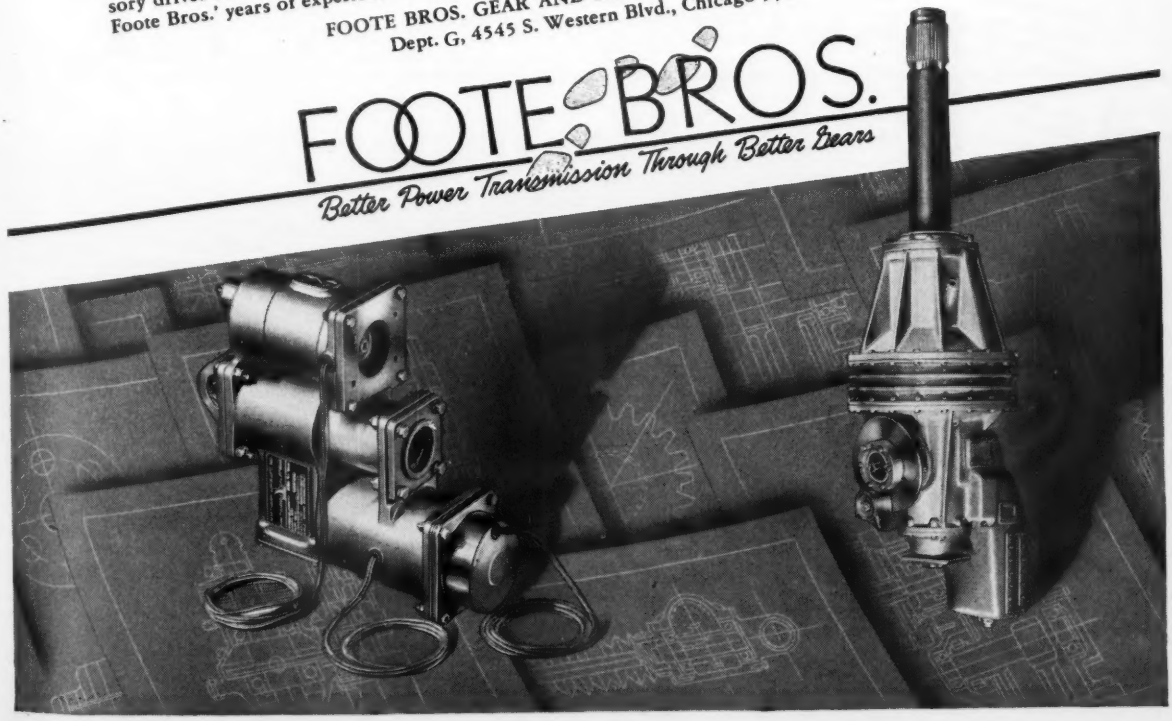

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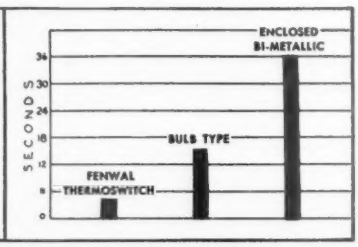

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Restricted Report No. E6C05 (*Wartime Report No. E-237*), March, 1946. 45 pp., figs. 8 references.

Chemisch-Physikalische Versuchsanstalt der Marine, Kiel, Germany: Fuels, Lubricants, and Organisation. W. H. Thomas and J. G. Withers. *Gt. Brit., British Intelligence Objectives Sub-Committee, Final Report No. 1210, Item No. 30*, October 10–19, 1945. 31 pp., diagrs. British Information Services, New York. $1.15. Replies to a standard questionnaire on fuel characteristics, methods of rating, and testing and performance.

Gliders & Gliding (35)

Centre of Gravity-Launch. II. Heinz Funk. *Sailplane and Glider*, Vol. 16, No. 2, February, 1948, pp. 2, 3, illus. (Cf. AER 5/48:51.)

An analysis of the bending moments to which glider wings may be subjected during center of gravity launching. At cable angles approaching 90° inept operation or gusts may cause a vertical lift component in excess of the safety factor of the structure. This method of launching should only be used after a thorough investigation of the weight, structural strength, safety factors, and lift characteristics of the craft. At all times a shear link should be used with the tow cable.

Tug and Towed Glider Rate of Climb. R. D. Hiscocks. *Soaring*, Vol. 11, Nos. 11–12, November–December, 1947, pp. 6–8, illus. A detailed elementary method of calculating the rate and angle of climb of an airplane towing a glider.

New Czech Sailplane (VLP-1 "Sroubek Ferdik"). Horejsi Milan. *Sailplane and Glider*, Vol. 16, No. 3, March, 1948, pp. 2–4, illus., diagrs.

Guided Missiles (1)

Guided Bombs in World War II. L. O. Grondahl. *Franklin Institute, Journal*, Vol. 245, No. 2, February, 1948, pp. 87–99, illus.

A history of the research, development, engineering, and combat employment of Azon (VB-1, VB-2), a high-angle bomb with line-of-sight azimuth control, and the subsequent application of its principles to Razon (VB-3), a model incorporating range as well as azimuth control.

First Steps in Supersonics. Norman MacMillan. *Aeronautics*, Vol. 18, No. 4, March, 1948, pp. 40–43, illus.

A general description of the first launching in May, 1947, of a Vickers transonic rocket. This was the first in a program of the Ministry of Supply in which rocket-propelled air-launched model aircraft were used to telemeter flight data to ground stations in an attempt to determine the change in lift and drag characteristics occasioned by transonic velocities and the changes in trim and stability of aircraft at supersonic speeds. The ground installations and the testing range are described. Brief bibliographical notes on the principal personnel are included.

Operation Rumpelkammer. *The Aeroplane Spotter*, Vol. 9, No. 208, March 6, 1948, pp. 54, 55, illus. A detailed account of the development and employment of flying bombs by Germany during World War II.

Hydrodynamics (21)

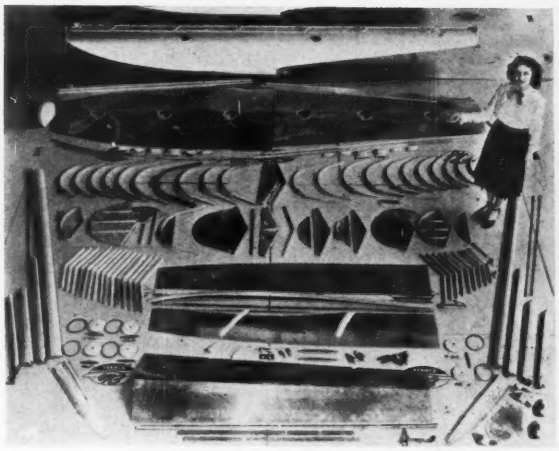
Preliminary Tests in the NACA Tank to Investigate the Fundamental Characteristics of Hydrofoils. Kenneth E. Ward and Norman S. Land. *U.S., N.A.C.A., Advance Confidential Report* (*Wartime Report No. L-766*), September, 1940. 38 pp., illus. 13 references.

Installations

UNDERGROUND (32)

German Underground Installations. I—Unique Design and Construction Methods. *Joint Intelligence Objectives Agency, Final Report No. 1*, September, 1945. 264 pp., illus., diagrs. British Information Services, New York. $6.50.

Describes the erection of a 1,312-ft. concrete arch with a 272-ft. span. This arch, 40 per cent of which was underground, served as air-raid protection for a semiunderground Messerschmitt airplane factory at Landsburg near Munich. Three similar installations were under construction. The factory buildings were made of prefabricated concrete members cast in heated forms at a central site. Another Messerschmitt plant, although not complete, was in operation at St. Georgen, Austria, producing jet aircraft. This site was tunneled out of sandstone cliff as were the German Goering Werke at Langenstein. The Eugen Grill Werke, an airplane factory, were to be installed in a system of tunnels in a limestone cliff near Salzburg, Austria. Details are given of the designs of the plants, the factors determining the site selection, the principal construction features, and the provisions made for ventilation, drainage, sewage, and lighting.



The demand for great strength and lightness in seaplane floats results in the highly complex structure of 179 individual parts which go into a single Edo float. Approximately 6,000 rivets are used in the final assembly.

Industry Underground: U.S. Industry Must Not be the Pearl Harbor of Tomorrow. Ira W. MacBride. *Ordnance*, Vol. 32, No. 167, March-April, 1948, pp. 313–315, illus. A discussion of the advantages of underground dispersal of war-potential industries and the technical, commercial, and psychological problems posed by such a program.

Instruments (9)

Calibration of Altimeters Under Pressure Conditions Simulating Dives and Climbs. Daniel P. Johnson. *U.S., N.A.C.A., Technical Note No. 1562*, March, 1948. 43 pp., illus., diagrs., tables. 8 references.

A procedure for calibrating altimeters under pressures varying in time to simulate conditions in dives and climbs at rates up to 30,000 ft. per min. A specially designed liquid manometer was used as a primary standard. Two types of precision aneroid barometers were found to be satisfactory secondary standards. At 30,000 ft. per min., the average dynamic lag or change of correction between high and low rates of altitude change was to less than 30 ft. for the best service altimeters that were tested. In erratic instruments dynamic lags larger than 100 ft. were observed. The variation of dynamic lag with reading, while irregular, was found to be highly reproducible.

Reflex Horizon. Ulrich K. Henschke and Hans A. Mauch. *U.S., Army Air Forces, Air Materiel Command, Engineering Division, Aero Medical Laboratory, Memorandum Report No. TSEAA-696-110B* (*GS-AAF-Wright Field No. 82*), December 12, 1947. 11 pp., illus.

Description of the optical and the kinetic system used in the first model of the reflex horizon. Attitude and course are displayed in an attempt to imitate contact-flying cues by presenting to the pilot, in the direction of flight at infinite focus, a spherical coordinate system that is kept fixed in space and on which a line always coincides with the natural horizon.

A Study of the Improvement of Displays for Attitude and Course Indication. *U.S., Air Force, Air Materiel Command, Engineering Division, Aero Medical Laboratory, Memorandum Report No. TSEAA-696-110A* (*GS-AAF-Wright Feld No. 81*), November 12, 1947. 18 pp., illus.

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A New Type of Servo-Accelerometer and Aircraft Dive Angle Indicator. Donald H. Jacobs. *Review of Scientific Instruments*, Vol. 19, No. 2, February, 1948, pp. 118, 119, diagrs.

A stiff leaf-spring pendulum arm is sensitive to acceleration. The stiffness of the spring can be varied with the rotary angular position of a motor-driven cam and follower. Deviation from the neutral position closes electrical circuits and selectively causes the cam-drive clutches to rotate the cam clockwise or counterclockwise. With the pendulum constrained to lie horizontal with reference to the longitudinal axis of the aircraft the device was used as a dive-angle indicator. In this application it gave indications accurate to within 0.5° but possessed too high a sensitivity for practical application.

The Magnetic Fluid Clutch. *U.S., National Bureau of Standards, Technical Report No. 1213*, March, 1948. 30 pp., illus.

The space between two clutch faces is filled with finely divided magnetic particles such as iron dust. When a magnetic field is established between the plates the magnetic particles form chains that bind the two-clutch surfaces. The linearity of the transmitted torque, smoothness of operation, and the virtual absence of wearing surfaces suit these clutches for application in servomechanisms. Developed by Jacob Rabinow of the National Bureau of Standards.

Electrical Tachometers, Small Generators, and Indicators. D. Edmunson and J. Dean. *Gt. Brit., British Intelligence Objectives Sub-Committee, Final Report No. 1537, Item No. 9*, October 11, 1946. 34 pp., illus. British Information Services, New York. $1.15.

A report of the inspection of 16 producers of tachometer generators; conventional moving-coil and "long-scale" indicators; inductor, contact-making, and conventional magnetic drag instruments; and magnetic materials. Advances were noted in the design of miniature stationary-core d.c. and induction a.c. generators. Improvement had been made in the quality of Tromalite, a permanent-magnet material developed by Max Baerman of Cologne, and in the quality of sintered-metal permanent magnets. The composition, characteristics, fabrication, and molding of Tromalite is described. The development noted in the design of "long-scale" indicators and moving-magnet d.c. instruments is attributed to the improvement that had been made in permanent-magnet materials.

A Supersensitive Tachometer. E. B. Brown. *Journal of Scientific Instruments*, Vol. 25, No. 2, February, 1948, pp. 47, 48, diagrs.

A condenser was placed in series with the indicator magnet of a magneto-generator in which the two separate phase-windings are in quadrature. At speeds close to that at which series resonance occurs, a 2 or 3 per cent variation in speed moved the pointer over the whole scale with a deflection that was approximately linear with the speed.

Laws & Regulations (44)

Legal Difficulties in Secured Airline Equipment Financing. Frederick E. Hines. *Journal of Air Law and Commerce*, Vol. 15, No. 1, Winter, 1948, pp. 11–26.

A discussion of the legal obstacles that hinder the development of secured financing of air-line equipment. Amendments have been proposed to the Civil Aeronautics Act and the Bankruptcy Act, and a covenant is being drafted by the ICAO which will (1) eliminate the possible liability for ground damage to persons and property of the holder of security interest, (2) establish the right of immediate repossession in bankruptcy, (3) provide effective recording of interests in spare parts, (4) remove any conflict with the Trust Indenture Act of 1939 in the case of public issue of securities backed by air-line equipment, and (5) will provide for the international recognition or recording of interest in aircraft.

Possible Simplification of the Warsaw Convention Liability Rules. Sune Wetter. *Journal of Air Law and Commerce*, Vol. 15, No. 1, Winter, 1948, pp. 1–10. 2 references.

The liability provisions of the Warsaw Convention could be greatly simplified, could obtain equity for both public and carrier, and could be applied universally if the carriers were to be held to an unconditional limited liability. The elimination of questions of willful misconduct, "dol," would reduce the settlement of claims to a simple appraisal of damage or loss, eliminate tedious investigations, and simplify air-transport underwriting.

Maintenance (25)

How to Use Aircraft Lifting Bags. George Habian. *Aviation Maintenance & Operations*, Vol. 9, No. 4, March, 1948, pp. 36, 37, illus., diagrs. Arrangements of inflated bags for lifting two-engined and four-engined aircraft where space prevents the use of wing jacks. Procedure is outlined step by step, including storage and checking of the bags.

Servicing Tips for Airliners. XIX—Fuel Systems. Allen Merkin. *Aviation Maintenance & Operations*, Vol. 9, No. 4, March, 1948, p. 47. For the Lockheed Constellation and the Douglas DC-4 and DC-6.

Management & Finance (45)

Commercial-Transport Trends. I. M. Laddon. *Aero Digest*, Vol. 56, No. 3, March, 1948, pp. 19, 154, illus.

The restricted market for commercial transport aircraft and the high cost of development introduce such a high element of risk that there is little hope of private manufacturers introducing new designs unless given assistance by the Government.

Materials (8)

METALS & ALLOYS

A Summary of Heat Resistant Alloys From 1200° to 1800°F. I. Nicholas J. Grant, A. F. Frederickson, and M. E. Taylor. *Iron Age*, Vol. 161, No. 12, March 18, 1948, pp. 72–78, tables. 5 references. (Based on U.S. Bureau of Ships (Navy Dept.), Research Memorandum No. 3–47, Navships 25-330-12, September 1, 1947.)

A general discussion of the properties displayed by the six major groups of alloys reported in the literature published between 1940 and 1947 for high-temperature and high-stress applications. Four lists tabulate, for these 53 alloys, the trade name, number and composition; density value; coefficients of expansion from 70° to 180°F.; and their tensile properties between 70° and 2,000°F.

The Corrosion of Metals. IX—Magnesium and Its Alloys. *Sheet Metal Industries*, Vol. 25, No. 251, March, 1948, pp. 541–546, diagrs., tables. 4 references.

The position of magnesium in the electropotential series makes it and its alloys highly susceptible to galvanic corrosion. Proper design of joints in which the surfaces are isolated by a non-metallic compound, or in which they are joined by an aluminum alloy containing magnesium, and design that provides for drainage and ventilation can minimize this problem. Stress corrosion can be remedied by cladding with alloys not susceptible to stress corrosion. Tests have also shown that magnesium alloys display a marked susceptiblity to corrosion fatigue.

Supersonic Pulses Probe Metals to Hunt Flaws, Check Thickness. H. C. Drake and E. W. Moore. *Aviation Week*, Vol. 48, No. 12, March 22, 1948, pp. 21–23, illus. A description of the application of the Sperry Reflectoscope and Reflectogage to the quality control and inspection of Curtiss-Wright propellers.

A Calculation of Internal Stresses Due to Cold Extension or Compression. H. Brandenberger. (*Schweizer Archiv*, Vol. 13, Nos. 8, 9, August, September, 1947, pp. 232–238; 268–275.) *The Engineers' Digest*, Vol. 5, No. 2, February, 1948, pp. 67–70, diagrs. 4 references.

A calculation of the stress-hardening effects in a ductile material. The method involves the superimposition of the volume, the form, the lattice, and the space stresses. Tests on brass to determine the increase in yield strength confirmed the calculated values.

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NONMETALLIC MATERIALS

High Temperature Ceramics. E. L. Olcott. *Product Engineering*, Vol. 19, No. 3, March, 1948, pp. 110–112, illus.

A brief summary of the high temperature properties of ceramic paints and coatings; solid cast, sintered, or transfer-molded ceramics; and current methods of manufacturing and designing ceramic parts.

Bearing Jewels of Hardened Synthetic Spinel. W. F. Eppler. *U.S., Field Information Agency, Technical, Final Report No. 1038*, April 18, 1947. 40 pp., tables. 10 references.

Methods of heat-treatment and results of hardness tests. When the spinels have a composition of $MgO.4Al_2O_3$, a mechanical-corrosion hardness 64 per cent that of corundum, a Vickers hardness equalling that of corundum, and a shear strength 149 per cent that of corundum is obtained.

Durability of Glued Wood to Metal Joints; First Progress Report. Herbert W. Eickner. *U.S., Forest Products Laboratory, Madison, Wis., Report No. 1570*, June, 1947. 33 pp., illus.

An investigation of the comparative durability of wood-to-metal joints made by six commercial gluing processes. Test joints were subjected to exposure conditions selected to measure the resistance to water, high humidities, high and low temperatures, aircraft fluids, and weather, of painted and unpainted aluminum-to-wood and steel-to-wood joints.

Development of Strength in Yellow Birch Lap Joints Glued With Six Resorcinol-Resin Glues at Temperatures from 40° to 80°F. W. Z. Olson and R. F. Blomquist. *U.S., Forest Products Laboratory, Madison, Wis., Report No. 1565*, December, 1947. 15 pp., illus.

Results of tests with resorcinol glues indicate that if the joint is retained under pressure for about 24 hours a gluing temperature as low as 60°F. may be used. If the joints could be subsequently heated under moderate pressure to 140°F. the gluing temperature could possibly be lowered to 40°F. At 40° and 50°F. resorcinol-resin glues with aqueous formaldehyde solution as the hardening agent appeared to be somewhat more capable of curing to higher strengths than those in which paraformaldehyde was used as the hardener, although the glues developed strength at the same rate at 70° and 80°F. Resorcinol-resin glues that contained substantial amounts of phenol resin cured more slowly than those that contained little or no phenol resin.

Durability of Plywood Joints Made With One Melamine-, One Urea-, and Five Resorcinol-Resin Glues. W. Z. Olson and R. F. Blomquist. *U.S., Forest Products Laboratory, Madison, Wis., Report No. 1568*, October, 1947. 6 pp., tables.

A progress report of the results of 18 months' exposure to continuous and cyclic conditions of the temperature and humidity. The five resorcinol-resin glues generally showed similarity in behavior. Continuous exposure at 158°F. and 20 per cent relative humidity proved to be the most damaging condition of exposure. Joints made with the acid-catalyzed melamine-resin glue generally showed somewhat greater deterioration than those made with the resorcinol-resin glues. Joints made with urea-resin glue deteriorated to a much greater extent than did joints made with the other glues used in this study.

The Effects of Micro-Organisms on Adhesives. *Aero Research Limited, Aero Research Technical Notes, Bulletin No. 62*, February, 1948. 9 pp., illus. 6 references.

A summary of the results of research at the Forest Products Research Laboratory, Princes Risborough, and by the U.S. Department of Agriculture. Unextended synthetic resins showed excellent resistance both to extreme humidity and to microorganisms. Blood albumin, casein, and other organic adhesives, while resisting one or the other condition, were never able to withstand both. When they constituted more than 25 per cent of the adhesives, extenders used with urea-resin glues lowered their microorganism resistance considerably.

SANDWICH MATERIALS

Fatigue of Sandwich Constructions for Aircraft; Aluminum Face and Paper Honeycomb Core Sandwich Material Tested in Shear. Fred Warren. *U.S., Forest Products Laboratory, Madison, Wis., Report No. 1559-A*, December, 1947. 12 pp., illus.

Twenty-five assembled sandwich panels were tested at a ratio of minimum to maximum loading of 0.1 to determine their shear fatigue properties. The results of these tests and the corresponding S-N curve indicate a fatigue strength at 30 million cycles of approximately 48 per cent of the static strengths.

Investigations of Methods of Inspecting Bonds Between Cores and Faces of Sandwich Panels of the Aircraft Type. Bruce G. Heebink and Alvin A. Mohaupt. *U.S., Forest Products Laboratory, Madison, Wis., Report No. 1569*, September, 1947. 26 pp., illus.

The following nondestructive methods of testing to detect inferior bonds between the cores and faces of sandwich panels were investigated: visual inspection, special lighting, tapping, supersonic inspection, exposure to vacuum, vacuum-cup test, internal-pressure test, heating the complete panel, local heating, and button-tension tests. None of these methods, or combinations of them, was judged practical and dependable means of inspecting the quality of joints.

Fabrication of Lightweight Sandwich Panels of the Aircraft Type. Bruce G. Heebink, Alvin A. Mohaupt, and John J. Kunzweiler. *U.S., Forest Products Laboratory, Madison, Wis., Report No. 1574*, June, 1947. 72 pp., illus.

A description of the materials used and the fabricating procedures adopted by the Forest Products Laboratory for the manufacture of test panels in connection with its project to establish design criteria for sandwich construction. Techniques were tested for the preparation of core materials, face materials, and for the assembly of panels of various combinations of plywood, aluminum, and glass-cloth face materials with balsa, cellular cellulose acetate, cellular hard rubber, paper honeycomb, and cotton-cloth honeycomb core materials. A summary is included of some of the manufacturing and fabricating techniques that were not considered satisfactory but which may be of value in future work on sandwich manufacture.

Meteorology (30)

Two Types of Sensitive Recording Cup Anemometer. E. L. Deacon. *Journal of Scientific Instruments*, Vol. 25, No. 2, February, 1948, pp. 44–47, diagrs. 3 references.

Both models used the Sheppard three-cup rotor and employed an electronic circuit to actuate telephone message registers. Low torque and bearing friction gave the instruments high sensitivity, constancy of calibration, and a stopping speed of 0.15 mile per sec. In one design the rotor carried an opaque semicircular sector to interrupt the light source of a photoelectric cell once each revolution of the rotor. In the other design a low-friction spindle, geared to the rotor, was met by a light electrical contact arm and served as an interrupter in the circuit of a thermionic tube. A special scale-of-two relay circuit reduced the rate of signal input to the registers to within their operating range. The register readings were recorded on bromide paper. The heat emitted by the lamp and by the thermionic tube protected the mechanism against climatic conditions.

A New Moisture-Meter: The Diffusion Hygrometer. H. Greinacher. (*Schweizerische Technische Zeitschrift*, No. 13, March 27, 1947, pp. 189–194.) *The Engineers' Digest*, Vol. 5, No. 2, February, 1948, pp. 87, 88, diagrs.

The mouth of a vessel containing a drying agent is closed with a semipermeable membrane (porcelain). The difference in pressure between the interior of the vessel and the atmosphere is the partial pressure of the water vapor in the air. This reading can be used to calculate the relative humidity of the air.

Moisture Measurement With an Electronic Dew Point Indicator. Verner E. Suomi. *Instruments*, Vol. 21, No. 2, February, 1948, pp. 178–182, illus., diagrs. 16 references.

A mirror is heated by a radio-frequency induction heater. The heater is regulated by a photoelectric cell controlled by the variations in the moisture deposit on the surface of the mirror. The instrument has measured dew points ranging from 30°C. to —67°C. with an accuracy of 0.4°C. Its average response is in the vicinity of 6°F. per sec.

The Problem of Air Flow Over Mountains; A Summary of Theoretical Studies. Paul Queney. *American Meteorological Society, Bulletin*, Vol. 29, No. 1, January, 1948, pp. 16–26, diagrs. 16 references.

The theoretical researches on the problem of the disturbance of an atmospheric current flowing over a mountain range, carried on during the last 10 years, prove that most of the characteristic observed features can be explained, to a large extent, by the hydrodynamic theory of internal, small, adiabatic perturbations in a stratified rotating atmosphere.

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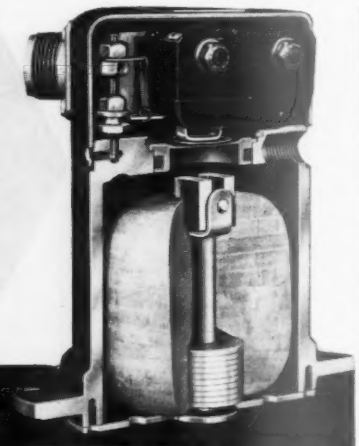

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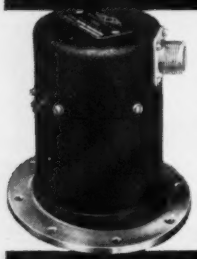

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On the Slope of Low-Pressure Axes as a Criterion for Deepening in the Tropics. R. H. Simpson. *American Meteorological Society, Bulletin*, Vol. 29, No. 1, January, 1948, pp. 9–15, diagrs. 7 references.

Operations

COMMERCIAL (41)

Pattern for Air Transport. E. T. House. *Aeronautics*, Vol. 18, No. 4, March, 1948, pp. 22–29, diagrs.

A comprehensive and detailed study of the commercial, technical, and financial factors to be considered in planning the initial establishment, the expansion, or the modification of an air-transport service. After a discussion of the overall planning, route selection, stage load factor, and equipment selection, a specimen working timetable is set up to show the interplay of commercial, operational, and maintenance factors, and the importance of seasonal climatic variations and aircraft performance.

History of Air Freight Tariffs. Harold W. Torgerson. *Journal of Air Law and Commerce*, Vol. 15, No. 1, Winter, 1948, pp. 47–63.

A summary of the changes in rates, commodity classifications, preferential rates, and ground handling services of the certificated air-cargo carriers from 1941 until the appearance of the non-certificated carrier in 1945. To meet this new competition some certificated carriers filed a consolidated tariff, and Air Cargo, Inc., was organized. The rates of both types of carrier continued to be down-graded until November, 1947, when the C.A.B. ordered a suspension of all rate reductions pending an investigation.

Cargo Volume Waits on Regularity. John H. Frederick. *Distribution Age*, Vol. 47, No. 3, March, 1948, pp. 40, 50, 51, 63, illus.

All-weather flying is prerequisite for the development of adequate air-cargo transport volume. Since the navigation and control facilities that are required are of such complexity and cost that they cannot be installed by private industry, the responsibility for their establishment rests with the federal Government.

California Eastern's New Communication System. Allan A. Barrie. *Distribution Age*, Vol. 47, No. 3, March, 1948, pp. 54–56, illus.

After departure of the flight, air bills are made up at the originating station and transmitted to stations of destination by a private-line teletypewriter service. This procedure has reduced the elapsed time of a coast-to-coast flight by 1 hour and supplying the terminus with advance information as to the nature of the cargo has made possible more efficient service to the consignee.

Airport Service and Delivery. William R. Nelson. *Aviation Maintenance & Operations*, Vol. 9, No. 4, March, 1948, pp. 29–31, illus. The freight handling and delivery service provided by the Airport Service & Delivery Co. at Lockheed Air Terminal.

The Paradox of the Airlines. LaMotte T. Cohu. *Preprint, S.A.E. Annual Meeting*, New York, April 15, 1948. 27 pp.

The failure of air lines to show a profit in 1947 is to be attributed, not to a lack of efficiency, but to inadequate financing, imprudent expansion, duplication of routes, and inconsistency on the part of the Government in applying its regulations. The failure to show a profit can be avoided if the C.A.B. revises its policy to reflect truly the intent of Congress and if both air-line management and labor are prudent and efficient in their planning.

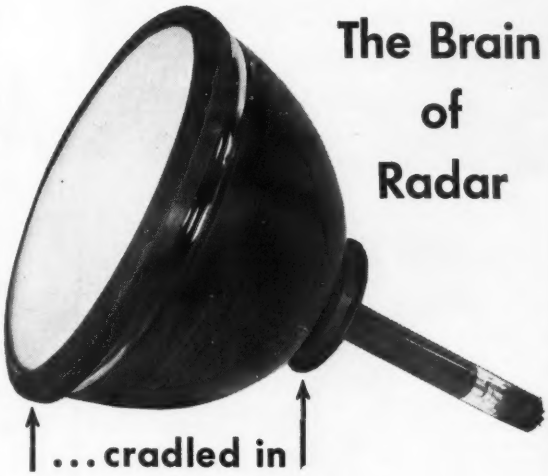
Air Transportation (Basic Information Sources). *U.S. Department of Commerce, Inquiry Reference Service*, April, 1948. 10 pp.

A list of 149 basic sources of information on the transportation of passengers and cargo by air. Governmental and nongovernmental publications, directories, trade papers, services, and associations are included.

Photography (26)

Lenses of Extremely Wide Angle For Airplane Mapping. Irvine C. Gardner and Francis E. Washer. *U.S., National Bureau of Standards, Journal of Research*, Vol. 40, No. 2, February, 1948, pp. 93–103, illus. 6 references. Available also as Research Paper RP1858, Govt. Printing Office, Washington, $0.40.

The Pleon camera lens and rectifying lens, designed by R. Richter of Zeiss, compensates for the variation in intensity of illumination in the image it produces by introducing a distortion of 68.8 mm. at the periphery of the 130° field. The distorted



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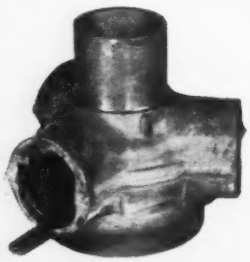
Two halves of forged nickel-chromium-molybdenum steel propeller barrel, machined and ready for assembly by pressure welding into a one-piece hub.



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A special welding process for producing the new hub was developed by Wyman-Gordon Company, Worcester, Mass., which fabricates these parts for Hamilton Standard Propellers Division of United Aircraft Corporation, East Hartford, Conn.

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negative is printed in the Pleon rectifier, the lens system of which introduces a compensating positive distortion. Detailed calculations have been made of the resolving power, the effective size of the entrance pupil for different angular distances from the axis, and of the net distortion of the two systems.

Oscillograph Photography With the Fairchild Oscillo-Record Camera. *Fairchild Camera and Instrument Corporation*, April, 1948. 11 pp., illus.

Specifications, general description of the operation, and specimens of traces recorded by the Fairchild Oscillo-Record Camera. This instrument is designed for both still and continuous motion photography on standard 35-mm. film. The periscope mount through which the image is reflected to the camera also provides a port for simultaneous viewing.

Wartime Naval Photography of the Electronic Image. Francis X. Clasby and Robert A. Koch. *Society of Motion Picture Engineers, Journal*, Vol. 50, No. 3, March, 1948, pp. 189–198, illus. The photographic and processing techniques developed by the U.S. Navy during the production of training films for the instruction of radar observers.

The High-Speed Spark Camera. Alfred Keil. *U.S., Navy, The David W. Taylor Model Basin, Translation No. 207*, September, 1947. 13 pp., illus.

A bank of 24 electronically controlled spark gaps produces a succession of intense flashes of 10^{-6} second duration. The interval between the flashes can be varied between 5×10^{-5} to 1×10^{-6} seconds. Each flash passes through a lens system to its mated objective in a 24-lens camera. The film plate remains stationary. Electronic circuits, design, operation, and operating data are included.

High-Speed Motion Pictures with Synchronized Multiflash Lighting. R. A. Anderson and W. T. Whelan. *Society of Motion Picture Engineers, Journal*, Vol. 50, No. 3, March, 1948, pp. 199–207, illus. 2 references.

Equipment to synchronize a high-intensity flashlamp with a high-speed motion-picture camera. The camera was a 16-mm., rotating-prism type and synchronization was accomplished by a brush-type contactor built into the camera. The electrical signal from the contactor was sent through a pulse-forming circuit to a trigger tube in the flashlamp circuit. Resolving-power tests showed the marked superiority of flash-lighting over continuous light.

The Metal-Diazonium System for Photographic Reproduction. R. J. H. Alink, C. J. Dippel, and K. J. Keuning. *Philips Technical Review*, Vol. 9, No. 10, 1947–1948, pp. 289–300, illus.

A copying system that produces a negative with a resolving power greater than 1,000 lines per mm. and a gamma range that can be varied between 6 and 8. The light sensitivity of the system is from 20 to 25 times that of the usual diazonium. The system was developed for the reproduction of moving-picture film and offers an efficient and practical method in the field of micro- and macrodocumentation.

Power Plants

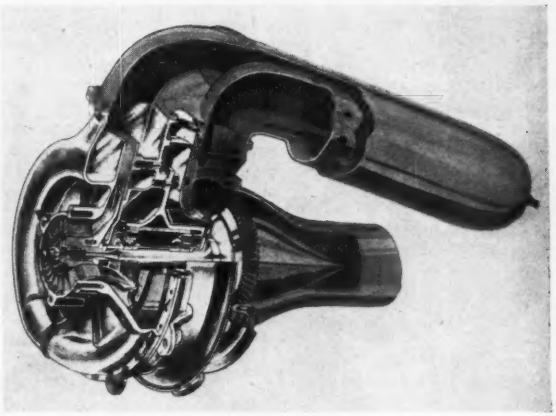
JET & TURBINE (5)

Service Experience with Turbojet Engines. J. W. Bailey. *Aeronautical Engineering Review*, Vol. 7, No. 6, June, 1948, pp. 30–36, illus.

During its three years of development, service experience obtained with the J-33 turbojet engine has been combined with endurance testing to improve the design of its components. A flexible pipe was used to link the tailpipe of the aircraft with the tail cone of the engine. A duplicate auxiliary fuel system and a spark-plug installation redesigned to eliminate the accretion of carbon on the points have assured the feasibility of starting at altitudes and have removed the danger presented by flame blowout. Failure of the turbine and compressor rotors and blades, and failure of the burner liners have led to the development of improved inspection and testing techniques. During this period the take-off power/weight ratio of the J-33 increased by 50 per cent and the time between overhauls was extended from 10 to 200 hours.

Vibration Analysis in Jet Engines. R. N. Hadwin. *de Havilland Gazette*, No. 43, February, 1948, pp. 6–9, illus.

In order to determine the cause of failure of impeller blades a program of vibration response testing was undertaken. By means of an electromagnetic vibrator and pickup the nodal lines of the various modes of vibration of the blade were located. Strain gages were cemented to the blade and their indications transmitted through a special air-cooled commutator ring adaptation of the rotor shaft to a six-channel camera-recording cathode-ray oscilloscope. From the record of the frequency magnitude and response obtained after successive modifications of the blades it was possible to develop a blade shape with safe stress peaks.



Official U.S. Navy Photograph

Tiny experimental jet engine developed for the Navy to fulfill a need for a cheap, expendable power plant to be used in target drones. Surplus turbosuperchargers, with a combustion chamber added, have been utilized to good advantage for this purpose. The 181-lb. power plant develops 214 lbs. of static thrust.

The Design of Contra-Flow Heat Exchangers. E. Schmidt. (*Paper presented before the Institution of Mechanical Engineers*, January, 1948.) *The Engineers' Digest*, Vol. 5, No. 2, February, 1948, pp. 55–60, figs.

A method of calculation in which the essential dimensions are given as functions of the initial design conditions of the exchanger and the properties of the fluid. It is possible thus to design for minimum weight and minimum volume.

A Laboratory for Gas-Turbine Development; Significant Features of Facility Operated by Westinghouse Electric Corporation. Winston R. New. *Mechanical Engineering*, Vol. 70, No. 3, March, 1948, pp. 195–204, illus.

RECIPROCATING (6)

Metallurgical Examination of a Japanese Sakae-21 Aircraft Engine. L. H. Grenell, J. R. Cady, and H. W. Gillett. *Gt. Brit., British Intelligence Objectives Sub-Committee, Report No. B.I.O.S./J.A.P./P.R./1467*, August 8, 1944. 71 pp., illus. British Information Services, New York. $2.75.

A detailed report on the materials used in the radial aircraft engine of a Hamp Mark II Japanese fighter aircraft. Excellent material and workmanship throughout showed no attempt to conserve critical materials or man power. Alloyed steels and forgings were used extensively. The quality of the gas-welded joints in the motor mount and ignition assembly was excellent. The high-quality machining operations and surface finishing noted on most parts indicated a lack of understanding of the value of good surface finish. The surfaces of highly polished articulating rods were marred by deeply stamped numbers, and the crankshaft counterweights in which no stresses existed were carefully polished. Numerous bearing alloys were used which showed an understanding of the service conditions encountered and an intelligent selection of materials.

Improved Baffle Designs for Air-Cooled Engine Cylinders. Abe Silverstein and George F. Kinghorn. *U.S., N.A.C.A., Advance Restricted Report No. 3H16* (*Wartime Report No. L-767*), August, 1943. 35 pp., illus. 3 references.

Aircraft Power Plant Engineering. Frank Nixon. *Shell Aviation News*, No. 116, February, 1948, pp. 19–21, illus.

How to Install a Mechanical Safety Starter on a Light Plane. Charles W. Merydith. *Canadian Aviation*, Vol. 21, No. 3, March, 1948, pp. 36, 38, 40, illus. A series of photographs illustrating the installation of a McDowell Safety Starter on a 1941 BC-12-65 Taylorcraft.

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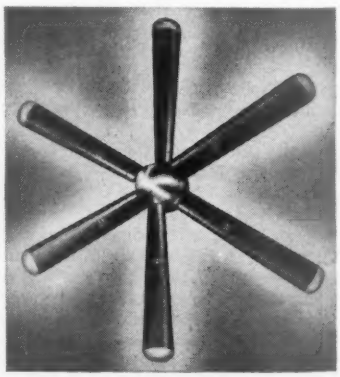

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Production (36)

Designing With Dollars. John Van Hamersveld. *Product Engineering*, Vol. 19, No. 3, March, 1948, pp. 81–86, illus., tables.

The cost control group of The Glenn L. Martin Company provides their engineers with current cost data. Two bulletins, *Comparative Cost of Materials* and *Comparative Cost of Standard Parts*, supply an analysis in handy graphic and tabular form of both the direct and indirect cost of aircraft materials and components. The bulletin entitled *Design for Economy* is a collection of check lists such as might be used by a design checker in reviewing a set of drawings. Specimen cost curves, data sheets, and comparative cost summary charts are included.

Stamping from Molten Non-Ferrous Metals. N. A. Sokolov. (*Vestnik Inzhenerov i Tekhnikov* (U.S.S.R.), No. 9–10, 1946, pp. 301–306.) *The Engineers' Digest*, Vol. 5, No. 2, February, 1948, pp. 77–79, diagrs.

A description of the forming process in which the pressure applied to the molten metal is developed in and by the die itself. A standard Russian stamping machine, a typical set of dies, and the plant design are described.

The Pressure Welding of Aluminum Alloys. R. F. Tylecote. *Sheet Metal Industries*, Vol. 25, No. 251, March, 1948, pp. 574–578, illus. 6 references.

General principles of pressure welding sheet and bars; surface condition; welding temperature and pressure; welding time; alloys suitable for pressure welding; strength of pressure welds; details of pressure welding technique; and surface preparation and welding equipment.

High-Frequency Molding; Method Applied to Compound Curvatures in Wood. P. H. Bilhuber. *Mechanical Engineering*, Vol. 70, No. 3, March, 1948, pp. 213–216, illus.

A method used by Steinway & Sons in the manufacture of semispherical radomes in wood veneer which is similar in principle to the bag-molding process. The reproducibility of master molds is assured by casting them in a ceramic-like material from a master die. The forming temperature is obtained by high-frequency dielectric heating. A metal-spray coating on the mold serves as one electrode. A metal cloth cover conforming in shape to the assembled unit is the second electrode. An inflatable rubber shoe covering the second electrode and restrained by a caul (a roughly shaped wood counterpart of the mold) is inflated to the pressure required in the process.

Industrial Applications of Ultrasonics: Researches Carried Out at Siemens-Schuckertwerke, Berlin. P. Alexander. *Gt. Brit., British Intelligence Objectives Sub-Committee, Final Report No. 1504, Items No. 21, 22.* 28 pp., illus, diagrs. British Information Services, New York. $1.15.

A description of three laboratory techniques employing magnetostriction, piezoelectric materials, or the principle of the Galton whistle that have been used to produce mechanical oscillations ranging from 10 to 3,000 kc. These techniques have been successfully applied to fluxless soldering, high-speed emulsification, and the degassing of transformer oils.

Propellers (11)

Effect of Variation of Airscrew Tip Speed and Drag Critical Speeds at Two Forward Speeds. R. C. Pankhurst. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2179*, August, 1943. 32 pp., figs., tables. 7 references. British Information Services, New York. $1.90.

At forward speeds of 0.608 and 0.75 Mach in a range of rotational speed and advance ratio corresponding to tip Mach Numbers from 0.85 and 100, estimates were made of the changes in propeller efficiency caused by variation of the tip speed. Likewise the difference in the efficiency was estimated when the number of blades was increased from three to six, when counterrotating pairs of propellers were used, and when the solidity was increased by constant factors retaining the same relative distribution along the blade. A further estimate was made of the effect of increases in compressibility-drag power loss when the drag critical Mach Numbers were reduced throughout by 0.05. A tabulation of the power losses and efficiency of three-bladed, six-bladed, and contrarotating propellers operating near the optimum conditions for the three-bladed propellers presents the compiled results.

Design of a Fixed-Pitch Pusher Propeller Coupled to a Free-Running Turbine. A. B. Haines. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2207*, March, 1946. 13 pp., diagrs. 10 references. British Information Services, New York. $0.90.

A contrarotating turbine is mounted in the engine exhaust jet. The turbine is surrounded by, and attached to, rotating drums that form part of the exhaust duct. Multibladed fixed-pitch inducted pusher propellers are mounted on these drums. An investigation of the most efficient propeller design to augment the cruising thrust and an examination of its performance at the lower forward speeds under take-off and climb conditions shows that it offers outstanding advantages in weight and simplicity compared with a normal sized variable-pitch propeller geared to a turbine. Under cruising conditions the total thrust is increased about 38 per cent with either a slight improvement or no change in the thrust-weight ratio. Despite the fixed pitch, increases from 29 to 50 per cent in overall thrust of the unit can be achieved even at take-off.

Tests of a Landing Brake Propeller on a Fighter Aircraft. A. J. Wilson. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2228*, October, 1943. 7 pp., figs., table. 1 reference. British Information Services, New York. $0.55.

A propeller adapted for use as an air brake by reversal of pitch provided a retardation more than double the maximum obtainable using wheel brakes alone. Tests were conducted on a Spitfire II. The wheel brakes had to be used to maintain direction. The greatest effect was achieved when the propeller brake was operated during the hold-off following a fast flaps-up approach. The aircraft touched down immediately, and the full braking effect was then obtained by opening the throttle. The landing run was 330 yards compared with 710 yeards if wheel brakes only were used following this type of approach.

Aerodynamic Problems in the Design of Efficient Propellers. Edwin P. Hartman and Lewis Feldman. *U.S., N.A.C.A., Advance Confidential Report (Wartime Report No. L-753)*, August, 1942. 51 pp., figs., tables. 6 references.

An exposition of aerodynamic theory and its application to the design of high-efficiency high-speed propellers. Charts based on the work of Betz, Lock, and others are given from which may be obtained the blade loading that gives the minimum induced-energy loss. From a consideration of the effect of profile drag on the optimum plan form a fairly simple method is outlined for obtaining the blade shape giving minimum total energy loss. Criteria are also presented for choosing the lift coefficient, the blade width, and the blade-thickness ratio that will produce a minimum profile drag. A simple propeller design is carried through in two parts: (1) to find the optimum loading with profile drag assumed to be zero, and (2) to determine the best blade shape for that loading when a fixed thickness distribution is assumed.

An Annotated Bibliography of Cavitation. F. A. Raven, A. M. Feiler, and Anna Jespersen. *U.S., Navy, David Taylor Model Basin, Report No. R-81*, December, 1947. 205 pp.

An alphabetical list by author of approximately 800 references covering the published literature on cavitation. More than 243 sources are cited, including a work by L. Euler in 1754. Most of the articles were reviewed or verified by the bibliographers in either the stacks of the Library of Congress, the library of the National Bureau of Standards, or the library at the David Taylor Model Basin. The abstract or note accompanying each reference, when not available from the abstract journals and indexes consulted, has been supplied by the bibliographers.

Rotating Wing Aircraft (34)

Full-Scale Investigation of the Blade Motion of the PV-2 Helicopter Rotor. Eugene Migotsky. *U.S., N.A.C.A., Technical Note No. 1521*, March, 1948. 40 pp., illus., figs. 7 references.

The flapping and feathering motions of the 0.75-radius station were obtained experimentally for the PV-2 helicopter rotor over a range of forward-flight conditions with the rotor trimmed about a representative center-of-gravity location. A convenient set of charts has been made up from these data to give the basic performance characteristics of a fully articulated rotor. Theoretical calculations, based on the assumption of uniform inflow, are found to be approximately 1.0° to 1.5° smaller than the experimental values of the lateral component of the equivalent flapping. The experimental variations of the equivalent flapping with the

tip-speed ratio and the thrust coefficient, however, were in good agreement with theoretical calculations.

The Helicopter and Stability. Arthur M. Young. *American Helicopter*, Vol. 10, No. 1, March, 1948, pp. 6–10, 23–25, illus. 8 references.

An account of the experimental helicopter models that were developed in an attempt to solve the problem of helicopter stability. A solution was finally obtained by using as a base of reference to which to feather the rotor blades, an inertia bar rotating with the rotor but not partaking of the shifting of the mast inclination. This design was embodied in the Bell helicopter. The stability characteristics of the full-scale aircraft are reported in detail.

Notes on Kaman Tests Methods. G. F. Chaplin. *American Helicopter*, Vol. 10, No. 1, March, 1948, pp. 17, 18, illus.

A mechanical oscillator bench tested the friction dampers used to damp interblade motion. Variable frequency electronic vibrators were used to check coincidence of the natural frequencies of the fuselage with those developed by rotor system. A portable full-scale rotor test rig was used to conduct control and endurance tests under outdoor weather conditions.

The New SG Mark VI-D. M. Berry. *American Helicopter*, Vol. 10, No. 1, March, 1948, pp. 16, 27, 28, illus.

Hiller "360" Helicopter. *Shell Aviation News*, No. 116, February, 1948, pp. 22–23, illus.

The JOV-3 Tandem (Helicopter Engineering Research Corp.). Mariano Imperiali. *American Helicopter*, Vol. 10, No. 1, March, 1948, pp. 20, 27, 28, illus.

Safety & Rescue (15)

Airport Fire Protection—Is it Adequate? *Aviation Maintenance & Operations*, Vol. 9, No. 4, March, 1948, pp. 19–22, tables.

A survey of water-supply systems, hangar construction, fuel handling, alarm systems, lightning protection, extinguisher equipment, aircraft rescue and fire-control provisions, and fire protection personnel at 336 airports.

Sciences, General (33)

MECHANICS

Fretting Corrosion. *Lubrication*, Vol. 34, No. 3, March, 1948, pp. 25–36, illus. 5 references.

A summary of the results of investigations into the nature and methods of preventing the oxidation of the contact areas of loaded metal surfaces that are subjected to oscillatory or vibrating motion. The effect is due to the slipping of metal surfaces and may be retarded by the elimination of oxygen at contact surfaces, adequate lubrication, surface treatment to increase friction and prevent slipping or to increase the hardness of the surfaces, or by sufficiently increasing the motion in the operating region to maintain a protective lubricant film.

Stress Analysis & Structures (7)

Curved Plates in Compression. K. B. Jackson and A. H. Hall. *Canada, National Research Council, Aeronautical Report No. AR-1 (N.R.C. 1495, MM-180)*, 1947. 100 pp., illus. 10 references.

Description of testing technique and analysis of results of two series of tests. To determine their load-deformation relations, 155 curved and 24 flat aluminum-alloy plates with clamped edges were subjected to compression parallel to the axis of curvature. The deformations were determined by measurement of photographs showing the deflection of a hair-line shadow on the surface of the plate. The empirical equations derived expressed the critical buckling stress, the reduced buckling stress after loads exceeding the initial buckling stress, and the postbuckling behavior or effective width of the plates.

An Elaboration of the Criterion for Wing Torsional Stiffness. A. R. Collar, E. G. Broadbent, and Elizabeth B. Puttick. **Appendix—The Effect of Taper on Wing Flexure-Torsion Flutter Speeds.** E. G. Broadbent and Elizabeth B. Puttick. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2154*, January, 1946. 24 pp., diagrs. 22 references. British Information Services, New York. $1.45.

A brief history of the investigations that led to the adoption of the current criterion for wing torsional stiffness. More recent research has shown that the critical flutter speed may be sensitive to the position of the principle axis of inertia and the wing taper, which parameters do not appear in this criterion. A new nondimensional criterion is proposed that includes these parameters and makes allowance for compressibility. The investigation of the effects of taper on flutter speed described in the appendix is more complete than previous work on taper in that it studies the secondary effects taken on mode of distortion and on effective stiffness and investigates the best linear taper to use as an approximation for wings whose plan form is not straight tapered.

The Measurement of Structural Stiffnesses of Aircraft. E. G. Broadbent and D. L. Woodcock. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2208*, March, 1945. 15 pp., illus. 3 references. British Information Services, New York. $1.00.

A compilation of the methods recommended for testing the stiffness criteria of aircraft components in accordance with the current practices at the Royal Aircraft Establishment. The stiffness in general is expressed as the overall stiffness between two planes, and the flexural displacement is measured as angular rotations thus expressing the stiffness in pounds per feet per radian. The testing methods for wings, tail planes and fins, fuselages, control surfaces, and control circuit stiffness are treated separately. The appendixes give methods of measuring the deflections, methods of loading, and special considerations for sweptback wings.

Stresses in and General Instability of Monocoque Cylinders with Cutouts. VI—Calculation of the Buckling Load of Cylinders With Side Cutout Subjected to Pure Bending. N. J. Hoff, Bertram Klein, and Bruno A. Boley. *U.S., N.A.C.A., Technical Note No. 1436*, March, 1948. 30 pp., diagrs. 7 references.

A strain-energy theory was developed for the calculation of buckling load in general instability of circular reinforced monocoque cylinders that have a side cutout and are subjected to pure bending. When the theory was applied to test cylinders the following percentage deviations from the experimental values were obtained: for the 8-stringer series, 54.8, 32.4, and 16.1 per cent

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for the 45°, 90°, and the 135° cutout; and for the 16-stringer series with like cutouts, 47.4, 30.8, and —3.2 per cent.

The Buckling of a Column on Equally Spaced Deflectional and Rotational Springs. Bernard Budiansky, Paul Seide, and Robert A. Weinberger. *U.S., N.A.C.A., Technical Note No. 1519,* March, 1948. 42 pp., figs. 6 references.

Stability criteria are developed by the Rayleigh-Ritz method for a column on equally spaced deflectional and rotational supports. In the Fourier series that is chosen to represent the deflection curve of the buckled column the potential energy expression is minimized with respect to each of the unknown Fourier coefficients. The resulting equations are separated into independent sets, each set containing the coefficients corresponding to a particular mode, and a general expression for the stability criterion for each buckling mode is derived. Charts are given that relate deflectional spring stiffness, rotational spring stiffness, and buckling load, for columns having two, three, four, and an infinite number of spans.

Stress Distribution in a Beam of Orthotropic Material Subjected to a Concentrated Load. C. B. Smith and A. W. Voss. *U.S., N.A.C.A., Technical Note No. 1486,* March, 1948. 37 pp., figs. 9 references.

The stress distributions in a wood beam of rectangular cross section were derived in the form of an infinite series. This series, when reduced to a finite series and a closed form, gave an expression that took into consideration the orthotropic nature of wood, from which the stress distributions arising from a concentrated load might be determined. In order to estimate the accuracy of this method a test was conducted to determine the distribution of horizontal shear in the vicinity of a concentrated load. The test data verified the calculations as well as could be expected and proved this method to be more accurate than that based on the elementary theory of bending.

An Integral-Equation Approach to Problems of Vibrating Beams. II. Walter T. White. *Franklin Institute, Journal,* Vol. 245, No. 2, February, 1948, pp. 117–133, tables, figs. 7 references. (Cf. AER 5/48:66.)

The solution of problems in vibration by integral equations. This type of equation is highly effective; it offers a method of solution that is simpler than that employing differential equations because vibrations of physical properties and discontinuities appear under the integral sign where they cause no particular difficulty. The method is applicable not only when simple bending theory is used, but also when the effects of rotary inertia, shearing force, longitudinal inertia, and gyroscopic movement are taken into consideration. The influence of each factor on the deflection of the beam is considered as acting alone. By superposition all the individual influences are added to form the integral equation of the vibrating beam. The Green's functions thus obtained express the deflection at any point of the beam which is caused by the application of a unit-concentrated load at any other point and contain the boundary functions that once dealt with in the construction of the function require no further consideration. The equations can generally be solved most directly by successive approximations. The rapid convergence of the successive approximations permit the use of an ordinary calculating machine. When only approximate evaluations of the integrals are desired, the so-called perturbated kernel provides a method of approach to the solutions for the higher models of vibration in which the accuracy of the solution is evident. A twisted turbine blade is used to show the use of the integral-equation method in dealing with continuous systems where coupling exists. The agreement between the calculated natural frequencies and experimental values is better than ordinarily expected for so complex a problem.

Compressive Strength of 24S-T Aluminum-Alloy Flat Panels With Longitudinal Formed Hat-Section Stiffeners Having Four Ratios of Stiffener Thickness to Skin Thickness. William A. Hickman and Norris F. Dow. *U.S., N.A.C.A., Technical Note No. 1553,* March, 1948. 41 pp., illus., tables. 8 references.

The compression-panel test data for panels with stiffener-thickness/skin-thickness ratios of 0.1 and 0.63 have been consolidated with like data for ratios of 0.39 and 1.25. From these charts and graphs the effect is shown of the relative dimensions of a panel on the buckling stress and the average stress at failure.

Note on Airworthiness Statistics. A. G. Pugsley and R. A. Fairthorne. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2224,* May, 1939. 4 pp., figs. 9 references. British Information Services, New York. $0.35. Methods of evaluating structural loading and accident statistics to arrive at safety factors for aircraft structures.

Wind Tunnels & Laboratories*

The Difference Between the Spinning of Model and Full-Scale Aircraft. G. E. Pringle. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 1976,* May, 1943. 19 pp., diagrs. 5 references. British Information Services, New York. $1.15.

A review of the technique of model-spinning tests in order to improve the reliability of model standards as a criteria of full-scale performance. Some of the possible causes of error have been eliminated by presenting the difference between full-scale and model behavior numerically as a single parameter subject to statistical variation—e.g., the scale effect in units of yawing moment. In special cases the admission of a more complex variation may be advisable. If the model is unduly sensitive to applied rolling moments, the corresponding constituent of the overall scale effect is separated from the rest and is allowed for independently in order to arrive at a safe standard.

Electrical Resistance Strain Gages Applied to Wind Tunnel Balances. Elmer C. Lundquist. *Institute of the Aeronautical Sciences, Sherman M. Fairchild Publication Fund, Paper No. 102,* 1947. 13 pp., illus. 6 references. $0.80.

The use of strain gages of the electrical resistance type would simplify the mechanical components of wind-tunnel balance systems and would permit remote and rapid observations. The strain gages attached to those members that would otherwise transmit the aerodynamic reactions axially could eliminate deflections that would change the attitude of the wind-tunnel model, provided the stresses in the transmitting members were kept small except over a short length on which the strain gages would be attached. In spite of the high stresses that would be necessary to produce measurable strains, the overall elongation of such members could be limited to a negligible amount. In contrast to the relatively simple mechanical components of such a system, elaborate electrical equipment would be required for measuring or recording the changes in strain induced by forces or moments applied to the wind-tunnel model.

On Maximum Model Size for Wind Tunnel Investigations at High Subsonic Mach Numbers. E. Petersohn. *Sweden, Flygtekniska Försöksanstalten, Stockholm, Meddelande Nr. 23,* 1948. 12 pp., diagrs. Kr. 1:50. (In English.)

Two-dimensional measurements were made in a closed tunnel with a circular test section to establish experimentally the relation that may exist between the relative model size and the maximum velocity without introducing abnormally large effects from the tunnel walls. Comparison was made with the constriction that, under conditions of adiabatic flow, gives sonic velocity in the minimum tunnel section with the model in place.

Measurement of Velocity of Detonating Gas (Explosive). Stuart W. Benson, Jr. *Gt. Brit., British Intelligence Objectives Sub-Committee, Report No. B.I.O.S./J.A.P./P.R./324.* 5 pp., illus. British Information Services, New York. $0.35.

A method of measuring the velocity of detonation of gases. The expansion of a sound wave that is emitted from a point source at the instant of detonation is used as a time scale. The sound wave and the detonation wave are photographed simultaneously by the point source shadow method. Circuit diagram of the apparatus and specimens of the record are included.

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Books

Photoelasticity, Vol. 2

By Max M. Frocht. New York, John Wiley & Sons, Inc., 1948. 505 pp., illus., diagrs. $10.

This second volume on photoelasticity by Dr. Frocht represents the continuation of a discussion on that subject into its more advanced aspects.

The book divides naturally into three main sections.

The first deals with the mathematical theory of elasticity as applied to two-dimensional problems. While many will undoubtedly be familiar with this material, for those who are not it affords a good introduction. Nothing new is presented; however, several important problems are treated in far more detail than is normally found elsewhere. Side by side with the mathematical discussion are presented photoelastic results, and the excellent agreements should dispel the doubts of those who question the accuracy that can be obtained by photoelastic methods. In addition, St. Venant's principle is discussed and its application to experiment illustrated.

Of importance is the discussion of the application of photoelasticity to two-dimensional multiply-connected sections. It is known, from the theory of elasticity, that in general the stress distribution for such shapes is dependent on the value of Poisson's ratio of the material concerned, and thus the validity of the application of photoelastic results to similarly loaded multiply-connected metal specimens may reasonably be questioned, since the Poisson ratios will differ in general. However, both by discussion and by experiment it is shown that in many cases the differences in results obtained for the two classes of materials are negligible.

In the second section a discussion of lateral extensometers leads naturally to a detailed exposition on various methods of solving numerically and graphically Laplace's equation in two independent variables. The connection with the general subject matter is that, while the photoelasticity results give everywhere the difference of the two principal direct stresses, their sum is not so readily found. One method of obtaining the latter is via a lateral extensometer, but this method can be inaccurate. It is easily shown, however, that the sum of the principal direct stresses satisfies Laplace's equation, so that its solution affords an alternative approach.

Probably the most valuable contribution here is the graphical "linear rosette" method developed by Dr. Frocht, which makes it possible to obtain approximate results in any desired portion of the problem without having to consider the whole domain. Although no proof is given that the method will lead to a solution of Laplace's equation, comparison with results obtained by other means show that by it reasonably accurate results are obtained.

The third section, which deals with three-dimensional photoelasticity, is the most important of the volume. Here, of course, the subject is still in the developmental stage; however, it is shown that already it is possible to obtain results for a variety of problems, and, in particular, the frozen stress method can give results of fair accuracy. The techniques and equipment are described in considerable detail. This is of extreme value and should save many experimenters from considerable trouble.

A discussion on the application of three-dimensional photoelasticity to finding stress-concentration factors is included. Although this topic is not yet greatly appreciated by the engineer solely concerned with "static" elasticity, it is extremely relevant in fatigue problems, and here again examples show that stress-concentration factors for many problems of practical interest may be determined fairly accurately by photoelastic methods.

The book closes with an appendix devoted to the recently developed material, Fosterite, which holds promise of being a material from which large, intricate, three-dimensional models can be constructed.

In general the book is profusely illustrated with excellent "fringe" photos. Behind their clarity and sharpness is concealed a long time spent in developing a high degree of technique. It is an easy matter to obtain a fringe pattern; to obtain accurate, reliable results, however, requires considerable patience and attention to detail. This Dr. Frocht undoubtedly has.

There is little about the volume that may be queried. However, one or two minor points are noticeable. Thus, for instance, on page 240, reference is made to the Liebmann formula whereas Liebmann's name is usually coupled with an iterative process of numerically solving Laplace's equation rather than with the finite-difference approximation. Again, possibly more could have been said about the limitations of the present three-dimensional theory.

For many years Dr. Frocht has been outstanding in the field of photoelasticity, and this volume will continue to enhance his reputation.

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For information on I.A.S. Library Service Facilities, see page 55

Statements and opinions expressed in Book Reviews are to be understood as individual expressions and not necessarily those of the Institute.

Aerodynamics of the Oscillating Airfoil in Compressible Flow

By S. N. Karp, S. S. Shu, and H. Weil. Under the Supervision of M. A. Biot. (Brown University, Graduate Division of Applied Mathematics.) U.S. Air Force, Technical Report No. F-TR-1167-ND. Wright Field, Dayton, Ohio, U.S. Air Materiel Command, 1947. 56 pp., diagrs.

This monograph presents a systematic and clear development of the theory of nonstationary compressible isentropic flow as applied to the calculation of time-dependent forces acting upon an airfoil at subsonic and supersonic speeds. For the specialist it integrates, elaborates, and arranges in an intelligible form results that were originally only briefly sketched in technical reports written in the Italian and German languages. To others it offers a lucid presentation of an interesting and involved technical subject both from a physical and a mathematical point of view.

At the beginning the acceleration potential is introduced and discussed. The fundamental differential equation, valid for both subsonic and supersonic linearized airfoil theory, is derived and expressed in terms of the acceleration potential and the free-stream Mach Number. Since the boundary conditions differ for subsonic and supersonic flows, each of these is individually treated in separate chapters.

The subsonic case is treated by reducing the basic equation to an essentially time-independent wave equation for the acceleration potential. This is accomplished by assuming harmonic oscil-

lations. This assumption does not in principle restrict the generality of the solution, since the harmonic oscillations can be used as components in a Fourier analysis of a general motion. Boundary conditions are then carefully discussed from various points of view. The equation is reduced to Bessel's equation of zero order and a solution satisfying prescribed boundary conditions is found. A constant appearing in this solution is related to the lift.

The integral equation for the pressure distribution is derived by relating the downwash velocity to the acceleration potential. Possio's method for deriving this equation is discussed and compared. A solution to the integral equation is then obtained by considering both Shades' and Dietze's method for isolating the singularity of the kernel of the equation.

The boundary conditions defining the supersonic case are considered in some detail and then formulated mathematically. Various methods for solving the resulting equation are proposed and evaluated. Among these are a method due to Riemann, the method of distributed sources and sinks, Heaviside's method, and the method of discontinuous functions. A formula for the lift distribution is then obtained. Results corresponding to a harmonically oscillating wing are given. Formulas for numerical calculations are also contained in the monograph. This work is an extremely good example of the importance of interplay between physical and mathematical considerations for obtaining results of practical value to aeronautical engineering. A list of 37 references is included.

DR. PAUL LIEBER
Polytechnic Institute of Brooklyn

Personal Aircraft Business at Airports

By Lynn L. Bollinger and Arthur H. Tully, Jr. Boston, Harvard University, Graduate School of Business Administration, 1948. 348 pp. $4.25.

This is the first comprehensive study to be published on the fixed-base operator who sells and services personal aircraft and provides flight training charter flights and similar services related to personal flying at airports. The authors estimate that about 8,000 operators are in business. Data gathered on direct visits to 180 of these in 40 states, and through discussions with additional operators as well as local, state, and federal Government officials, provide the basis for this survey and the recommendations resulting from it. Part I deals with the product first of all, the influence of war, the effect of Government regulations, and the development of the business. These are the broader factors of environment over which the individual operator has little control. Recommendations in regard to the personal airplane are based on the conclusion that the important sales factor is its usefulness. The immediate future of the personal aircraft industry is largely dependent on the increased usefulness of its product which in turn depends on the attainment of a larger number of strategically located landing areas. If the airplane itself can be developed to use smaller landing areas safely and quietly, these are more important factors than speed between airports or lesser cost of today's airplane. The principal existing fallacy is that of the inevitability of the large-area outlying airport.

One conclusion is that annual sales of 40,000 to 60,000 airplanes are necessary to support the operators now in business, and sales of 30,000 will permit the majority to stay in business at a reduced scale of activity. Such production not only depends on more landing areas, but on a simplification of regulations affecting the operation and maintenance of personal airplanes and regulations governing aircraft design, construction, and fabrication. The greater part of the book is devoted to the financing and management of fixed-base operators and fixed-base operations at publicly owned airports; the latter are taken up in Parts II and III. The approaches used in determining capital requirements and financial plans by operators of varying size are reviewed, and earning experiences of 44 operators are analyzed with regard to the influence of various factors, including profitability of aircraft sales, flight training, and repair service. Chapters on "Problems of Expansion and Sales Promotion" and "Operational and Shop Control" are included. As 120 of the 180 fixed-base operations investigated were on publicly owned airports, problems of reconciling the objectives of community airport owners and tenant-operators and principles to help determine annual user charges are discussed. A flexible type of long-term lease is discussed in detail.

MAURICE H. SMITH
Curator-Librarian, I.A.S.

The Failure of Metals by Fatigue

Proceedings of a Symposium held in the University of Melbourne, December 2nd–6th, 1946. Melbourne, Australia, Melbourne University Press, 1947. 505 pp., illus., diagrs. 42s.

"Fatigue Problems Associated with Aircraft Materials," by H. Sutton, is a review of selected fields of investigation with special reference to simple conditions of loading, the influence of stress cycles of differing magnitude, effect of surface treatments on fatigue properties and means of improving fatigue performance. "The Factors Contributing to Fatigue Failure in Aircraft," by C. W. George, S. F. Grover, and B. Chalmers, reviews broadly such features influencing fatigue failure as materials, geometry of design, surface finish, service conditions, and stress sequence, and the results of examination of fatigue failure in flight and laboratory fatigue tests. "Repeated Loading on Struc-

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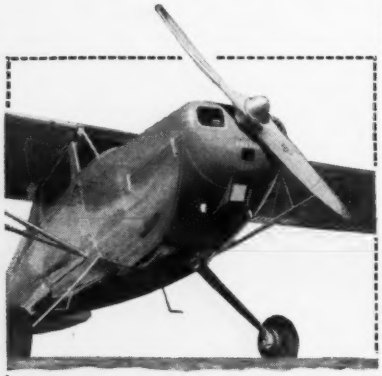

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tures," by A. G. Pugsley, considers loads repeated at intervals ranging from seconds to hours and at rates that may be regarded as gradual compared with the natural periods of the structures concerned, as in the case of an airplane in flight. "The Fatigue of Welded Steel Tubing in Aircraft Structures," by C. J. Osborn, reviews the fatigue strength of welded steel tubing, stresses in components employing welded tubular steel structures, and service failures.

"Notch Sensitivity of Metals," by M. S. Paterson, is a review of sources of stress concentrations, measurement of notch senstivity, theories of notch effects, relation to certain physical properties, and influence of mechanical factors. "Fatigue Problems in the Gas Turbine Aero Engine," by A. R. Edwards, discusses vibrations arising from aerodynamic causes, design features, aiming particularly to alleviate vibration and fatigue troubles, problems involved in the fatigue testing of turbine blades, and other specialized fatigue testing methods. F. W. Hooton, in "The Measurement of Dynamic Strain," gives the requirements and general principles of operation of various types of electrical and mechanical strain gages. The electrical resistance strain gage and its associated equipment are discussed in detail, including fields of application and the limitations of circuits which have been successfully used.

W. W. Johnstone, in "Methods of Investigating the Fatigue Properties of Materials," describes mechanical methods as used at the Division of Aeronautics of the Australian Council of Scientific and Industrial Research, with notes on other methods. F. S. Shaw, in "Determination of Stress Concentration Factors," reviews and discusses the relative merits of mathematical methods, direct measurements and photoelectric and other indirect experimental methods. G. G. McDonald, in "The Design of Cylindrical Shafts Subjected to Fluctuating Loading," applies the "maximum elastic distortional energy" theory of failure to the case of a cylindrical shaft subjected to combined fluctuating bending, twisting, and direct loads, and derives an expression for the design of such shafts. Experimental results on combined loading of cylindrical specimens are reviewed, and it is concluded that they confirm the formula. Additional papers include "The Failure of Metals by Fatigue," by J. Neill Greenwood; "Metallography, Fatigue of Metals and Conventional Stress Analysis," by H. F. Moore; "Theories of the Mechanism of Fatigue Failure," by W. Boas; "Structures Liable to Fatigue Failure and Some Considerations in Their Design," by L. R. Jackson and H. J. Grover; "The Detection of Fatigue Cracks," by C. W. Orr; "Photo-Elasticity and Stress Concentration," by W. H. H. Gibson; "Residual Stresses, Their Measurement and Their Effects on Structural Parts," by G. Sachs; "Fatigue of Bolts and Studs," by J. G. Ritchie; "Conditions Leading to Fa-

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tigue Failure in Sleeve Bearings," by R. W. K. Honeycombe; and "The Prevention of Fatigue Failures in Metal Parts by Shot Peening," by J. G. Brookman and L. Kiddle. Critical discussions accompany each paper and the volume contains about 575 literature references.

Book Notes

AERODYNAMICS

Summaries of Foreign and Domestic Reports on Compressible Flow. Brown University, Graduate Division of Applied Mathematics. (U.S., Air Force, Technical Reports Nos. F-TR-1168A-ND—1168D-ND.) Wright Field, Dayton, Ohio, U.S. Air Materiel Command, 1947. 4 Vols. 78, 100, 77, 112 pp., diagrs. These four volumes contain concise analyses of 100 reports in the field of compressible flow and related fields, with particular reference to German work of the war years by such authors as Busemann, Eckert and Drewitz, Haack, Hantzsche and Wendt, Pretsch, Sauer, Schlichting, Schultz-Grunow, and Tollmien. About a dozen of the summaries deal with reports from other countries by Ackeret, Feldmann and Rott, Biot, Crocco, Jarrick and Robinow, Imai, Possio, and Tetervin.

ELECTRONICS

Radio Aids to Navigation. R. A. Smith. Cambridge, at the University Press; New York, The Macmillan Company, 1948. 114 pp., figs. $2.50. The aim of the author is to present a balanced survey of the field of radio aids to navigation, with particular reference to aircraft. Following a review of prewar systems of radio navigation and their limitations, short-range systems are taken up, including radar interrogators and responder beacons, very-high-frequency direction finders, very-high-frequency ranges, and Gee. Long-range systems, including Loran, Consol, Post Office Position Indicator, and Decca, complete the first half of the book. Microwave radar navigational aids, special radar applications (including G-H, Rebecca-H, Shoran, and Oboe), and radio altimeters are next discussed. The book ends with chapters on continuous-wave and radar systems as aids to instrument landing, a short chapter on airfield control, and a review of navigational systems. British and German developments are well covered. Such American systems under development as DME (distance measuring equipment), the arbitrary course computor, Navaglobe, Teleran, Lanac, Navar, or Navascreen are not included. There is a useful glossary.

Electronics and Their Application in Industry and Research. Edited by Berward Lovell. London, Pilot Press, Ltd., 1947. 660 pp., illus., diagrs. 42s. This work is devoted primarily to the important growing fields of electronics in which developments during the last decade have been significant. It consists of 14 chapters by specialists, covering photocells for the infrared, radar, high-frequency heating, and electronics applied to servomechanisms. Subjects adequately dealt with elsewhere are excluded. The book contains more than 400 illustrations and diagrams. There are over 500 references and 100 books listed at the ends of chapters. A subject index and an author index are included.

Electronic Instruments. Edited by Ivan A. Greenwood, Jr., J. Vance Holdam, Jr., and Duncan Macrae, Jr. (Massachusetts Institute of Technology, Radiation Laboratory Series, No. 21.) New York, McGraw-Hill Book Co., Inc., 1948. 721 pp., diagrs. $9.00. While the authors believe that the field of utility of the instruments discussed is considerably wider than that of radar, the object of this book is to present the theory and practical details of these instruments as known to the radar engineer. Part I deals with automatic, electronic and electromechanical, analogue, single-purpose computers and computer elements as used in such applications as blind bombing, navigation, gunfire control, and radar trainers. Part II is devoted to electronic instrument servomechanisms, with some mention of nonelectronic devices. Part III deals with voltage and current regulators, and Part IV with pulse test equipment such as oscilloscopes with synchronized sweeps, synchronizers supplying trigger pulses and beam deflection voltages for an external cathode-ray tube, pulse and marker generators, and apparatus for the precise measurement of small time intervals. Footnote references are included.

Pulse Generators. Edited by G. N. Glasoe and J. V. Lebacqz. (Massachusetts Institute of Technology, Radiation Laboratory Series, No. 5.) New York, McGraw-Hill Book Co., Inc., 1948. 741 pp., illus., diagrs. $9.00. The purpose of this book is to present the basic principles underlying the design of pulse generators capable of producing a succession of pulses of a very short time duration, as used in the transmitters of microwave radar systems. As these techniques are applicable in many problems of engineering and physics involving loads of various types, the discussion is kept as general as possible. Part I deals with the hard-tube pulser, using a high-vacuum tube as a switch through which the conduction can be controlled by the application of the proper voltage to a grid. Part II is concerned with the line-type pulser utilizing the lumped-constant transmission line or line-stimulating network, and Part III takes up the design and characteristics of pulse transformers.

Microwave Magnetrons. Edited by George B. Collins. (Massachusetts Institute of Technology, Radiation Laboratory Series, No. 6.) New York, McGraw-Hill Book Company, Inc., 1948. 806 pp., illus., diagrs. $9.00. The aim of this work is to present as much as possible of what was known as of January, 1946, about the theory, design, and operation of magnetrons in the frequency range of 1,000 to 25,000 Mc. per sec. and the modifications that extend the usefulness of these tubes. While radar background causes emphasis on magnetrons intended for pulsed operation, the treatment is extended to continuous-wave applications when possible. The scope includes details of construction of production magnetrons as well as detailed theory of the various aspects of magnetron operation. A final chapter gives operating data and important dimensions for 17 different magnetrons.

INSTRUMENTS

Link Instructor Manual. Charles A. Zweng. North Hollywood, Calif., Pan American Navigation Service, 1948. 304 pp., diagrs. $4.00. This manual is designed for the Link Trainer instructor and contains the pertinent data required in preparation for the C.A.A. written examination for the Link Instructor Rating. The book consists of five sections, including instrument flying by both the 1-2-3 system and the "Full-Panel" system; the construction, operation, and maintenance of the Link Trainer; airway radio aids; Civil Air Regulations pertaining to instrument flying and the Link Trainer; and a final review section containing the 90 questions of the written C.A.A. examination.

OPERATIONS

COMMERCIAL

Wings Around the World; The Story of American International Transport. Burr W. Leyson. New York, E. P. Dutton & Co., 1948. 192 pp., illus. $3.00. The development of American international air services from their beginning in 1927 to the present day is presented, including the airplanes used in these services. The coverage for Pan American Airways is more complete than for other companies and the military and naval air transport services, and this weakens the later parts of the book. Maintenance practices, vocational opportunities, and a look into the future are discussed in the final chapters.

ORGANIZATIONS & SOCIETIES

Organizing Scientific Research for War; The Administrative History of the Office of Scientific Research and Development. Irvin Stewart. Boston, Little, Brown and Co., 1948. 358 pp. $5.00. This volume in the series entitled *Science in World War II* is concerned with the administrative framework and the legal basis of operation of the Office of Scientific Research and Development, established by executive order of the President in June, 1941. Technical accomplishments will be covered in four later volumes. The successful organization of the large team of scientists comprising O.S.R.D. and the success of their liaison with the armed services and with allied governments is ably described. There is a full index of names. The author, president of West Virginia University, was deputy administrator of O.S.R.D.

PERSONAL FLYING

Economics of Personal Airplane Operation. (Oregon State College, Engineering Experiment Station, Circular Series, No. 10.) Corvallis, Oregon, July, 1947. 46 pp., diagrs. $0.25. An analysis is made of the fixed costs, such as depreciation, interest on intial investment, hangar rental, and insurance; variable costs, such as fuel and oil, and maintenance and overhaul; and the nonflying expenses, such as ground transportation expenses, delay expense, and business expenses for commercial operation, invoved in the operation and ownership of airplanes up to a maximum cost of approximately $8,000 and a seating capacity of four to five persons including a pilot. A method of computing these costs is presented in chart form, including provision for combining variable and fixed costs in a final chart. The longer but more exact method of computation step by step is also outlined. A bibliography of thirteen articles is included.

PERSONNEL

Ground Instructor, Covering "General Aeronautics." 4th Ed. Charles A. Zweng. North Hollywood, Calif., Pan American Navigation Service, 1947. 427 pp., illus., diagrs. $3.00. In this edition of a book last revised in 1943, the purpose remains the same, to cover the basic course in preparation for the examination for the "Ground Instructor" rating under the Civil Air Regulations. The four basic subjects in which ground instructors can be rated are covered: Theory of Flight, Navigation, Meteorology, and Aircraft Power Plants. The chapters on Power Plants and Propellers are new. Navigation is treated in two chapters instead of one, Dead Reckoning Navigation and Radio Compass Navigation. The chapter on Meteorology covers 113 pages instead of 84 pages, and new material on such topics as high lift devices, variable wing area, variable camber, automatic slots, and trim tabs, has been added to the section on Theory of Flight.

POWER PLANTS

Aircraft Engines. Rollen H. Drake. New York, The Macmillan Co., 1948. 348 pp., diagrs. $5.90. Intended for the layman as well as the teacher and aircraft mechanic, this text is written in nontechnical language and without the use of mathematics. Materials, construction methods, theory of operation, and fundamental principles of reciprocating engines take up the greater part of the book. Propellers, jet propulsion, and engine instruments are included, and there is a glossary.

Aero Engines for Students, Including Gas Turbines. Revised and Enlarged Ed. R. A. Baumont. London, George Allen & Unwin, Ltd., 1947. 202 pp., illus., diagrs. In this revised edi-

tion of a book first published in 1943, a new chapter on the gas turbine has been added and new material on injection carburetors. The text has been revised throughout to include new material, and a number of new illustrations and drawings and an index have been added. The chapters on lubrication and ignition have been eliminated.

PRODUCTION

Sampling Inspection. Columbia University, Statistical Research Group. New York, McGraw-Hill Book Co., Inc., 1948. 395 pp., diagrs. $5.25. This book is intended as an account of current sampling inspection practices for quality control, with detailed instructions and tables for carrying out these practices. It is the first book to collect the scattered data on sampling inspection into one reference source. Sampling tables, a standard procedure for their use, the principles of this procedure, and the nature and uses of sampling inspection take the greater part of the book. A technical-mathematical discussion of the construction of the tables, and the procedure for their use is included, with a list of references and a glossary.

Materials-Handling Equipment; a Modern Manual. Matthew W. Potts. New York, Pitman Publishing Corp., 1947. 172 pp., illus. $2.50. This book defines and describes various standard types of conveyors, elevators, hand-operated trucks, skids, and jacks, hoisting machinery, trackless carriers, tractors and trailers, and other types of materials-handling equipment. Equipment usually used primarily by contractors and machinery used in the process industries are excluded. The usual applications of each piece of equipment are described.

REFERENCE & BIBLIOGRAPHY

Directory of Engineering Data Sources; a Guide to American Literature in Engineering and Related Sciences. Atlanta, Ga., 5009 Peachtree Road, Southeastern Research Institute, Inc., 1948. 63 pp. $2.50. This directory lists about 50 federal agencies, 80 universities, colleges, and state agencies, 160 scientific, technical, and trade organizations, and 200 commercial publishers of periodicals and books. The serial publications of organizations are usually included, with prices. In the classified section organizations and publications are listed according to 16 broad fields of interest, such as aeronautics, including meteorology.

The British Aircraft Industry, 1948. London, The Society of British Aircraft Constructors, Ltd., 1948. 279 pp. This directory of the members and associate members of The Society of British Aircraft Constructors, Ltd., includes brief descriptions of the products and activities of each company in English, French, and Spanish. A directory of trade names is included.

Whites Air Directory and Who's Who in New Zealand Aviation, No. 1. Auckland, N.Z., Whites Aviation Ltd., 1947. 140 pp. 7*s*. 6*d*. This directory aims to give all information relating to aviation in New Zealand and the South Pacific. Civil and military government agencies, air-line, aircraft, accessory, oil, insurance and other manufacturing and operating companies, societies and clubs, schools, training centers, and airports and seaplane bases are included. The Who's Who selection is limited to executives actively engaged in aviation and officers of the Royal New Zealand Air Force holding executive posts or having especially distinguished war records. The historical reviews and information on scholarships and awards are typical of the completeness of the directory. The lists of registered aircraft and license holders are complete as of September 30, 1947.

Index of NACA Technical Publications, 1915–1947. Washington, Division of Research Information, U.S. National Advisory Committee for Aeronautics, December 31, 1947. 385, 27, 6 pp. The importance of this index of more than 4,400 reports published by the National Advisory Committee for Aeronautics up to September, 1947, cannot be overestimated. Over 10,000 entries are given by author, title, report number, and date, chronologically under subjects. Most reports are listed under two or more subjects. The number of pages devoted to subjects is: Aerodynamics, 190; Hydrodynamics, 15; Propulsion, 56, Structures, 40; Materials, 25; Meteorology, 5; Operating Problems (ice prevention, noise, navigation, etc.), 14; Instruments, 11; Research Equipment and Techniques, 9. The total number of subjects, including subdivisions, is 450. Contents are listed in classified arrangement at the beginning and in alphabetical arrangement at the end of the volume. The index includes *Technical Memorandums*, *Technical Notes*, *Technical Reports*, *Aircraft Circulars*, and reports issued during World War II which have been declassified. There is no index of authors and no index of *Wartime Report* numbers. Reports inadvertently omitted are included in an appendix.

Index of NACA Reports Having Application to Personal Aircraft. Washington, National Advisory Committee for Aeronautics, September, 1946. 23 pp. About 600 *N.A.C.A. Reports*, *Technical Notes*, and *Technical Memorandums*, and reports issued during the war which have been declassified are listed under about 50 subjects and subdivisions of subjects of value in the design of personal aircraft.

Molesworth's Aeronautical Engineers Pocket-Book. 2nd Ed. Edited by Albert Peter Thurston. London, E. & F. N. Spon, Ltd., 1947. 532 pp., diagrs. 30*s*. Material in this new edition of a handbook first published in 1942 has been rearranged into sections, including Aerodynamics, Drawing Office Procedure and Design Data, Weights and Weight Estimation, Materials, Strength of Materials, Structures, The Power Unit, Mathematics, and conversion factors and other tables. About 200 pages of new material have been added. The rearrangement and the large amount of new material, such as I.C.A.N. altitude tables, have greatly increased the usefulness of this handbook, particularly in the materials and structures fields.

ROTATING WING AIRCRAFT

Helicopters of Tomorrow, the Rudiments of Rotating Wing Flight. B. J. Hurren. London, Staples Press, Ltd., 1947. 40 pp. 3*s*. The development of the autogiro, the helicopter, and the gyrodyne, employing a propeller mounted on a stub wing for both antitorque and forward flight power, are sketched briefly. Future possibilities in civil aviation for the helicopter are discussed in the last third of the book. A brief bibliography is included.

SAFETY & RESCUE

National Fire Codes. Vol. I. Flammable Liquids, Gases, Chemicals and Explosives. Compiled by Robert S. Moulton. Revised to December 31, 1947. Boston, National Fire Protection Association, 1948. 608 pp., diagrs. $4.00. Standards pertaining to the storage, handling, and utilization of gasoline, oil, kerosene, gases, explosives, and nitrocellulose materials are presented in the form of suggested ordinances and recommended good practice requirements. Tables of common hazardous chemicals, fire hazard properties of flammable materials, and materials subject to spontaneous heating are included. This edition supersedes similar volumes dated 1943 and 1945.

SCIENCES, GENERAL

GEOGRAPHY

Polar Exploration. Andrew Croft. 2nd Ed. London, Adam & Charles Black, 1947. 268 pp., illus., maps. 15*s*. First published in 1939, this new edition contains brief added material on the Canadian Army and Air Force "Exercise Musk-Ox," the United States Antarctic Service Expedition, the Falkland Island Dependencies Survey, and the navigation of the North-West Passage in 1940–1942 and 1944 by the Royal Canadian Mounted Police.

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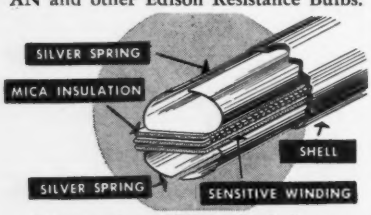

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MATHEMATICS

Integration in Finite Terms; Liouville's Theory of Elementary Methods. Joseph Fels Ritt. New York, Columbia University Press, 1948. 100 pp. $2.75. The work of Joseph Liouville, published between 1833 and 1841, concerning his theory of effecting integrations and solving differential equations by elementary methods, and of following studies by D. Mordukhai-Boltovskoi, A. Ostrowski, and the author are reviewed. Elementary functions of one variable, algebraic functions with elementary integrals, and integration of transcendental functions take up the first half of the book. The remainder is concerned with Kepler's equation, hypertranscendental functions and other questions on the elementary functions, series of fractional powers, integration of differential equations by quadratures, elementary solutions of differential equations of the first order, integrals of elementary functions, and linear differential equations of the second order. A brief bibliography is included.

STRESS ANALYSIS & STRUCTURES

Strength of Materials. Joseph Marin. New York, The Macmillan Co., 1948. 464 pp., illus., diagrs. $4.75. In this textbook for a first college engineering course, sections on mechanical properties are included in the chapters on single tension and bending, shear and torsion, and beam bending, to make possible the correlation between stress analysis, mechanical properties, and design for machine, structural, and aircraft design. Chapters on axial and bending loads for short members and long members or columns complete the first part. The second part deals with the determination of stress and theories of failure and design for members subjected to combined stresses. Part 3, on statically indeterminate stresses, deals with deflection methods of analysis, including the double-integration, moment-area, and moment-distribution methods, and a brief introduction to the energy method. Part 4 covers special topics: riveted and welded joints; special problems on bending of beams, and fatigue and impact loads. Centroids and moments of inertia of plane areas are covered in Appendix I, and Appendix II contains tables of physical properties and design stresses of common engineering materials. Footnote references are included. The author is a professor at Pennsylvania State College.

THERMODYNAMICS

Problems on Applied Thermodynamics. Revised Ed. Virgil Morning Faires, Alexander V. Brewer, and Clifford M. Simmang. New York, The Macmillan Co., 1948. 151 pp., charts. $1.70. About 1,115 problems, with answers for about half, and variations bringing the total to 1,427, are provided in this revised edition of a book first published in 1938. It is designed for use with V. M. Faires' *Applied Thermodynamics* but can be used with any textbook using standard terminology and emphasizing the general energy equation.

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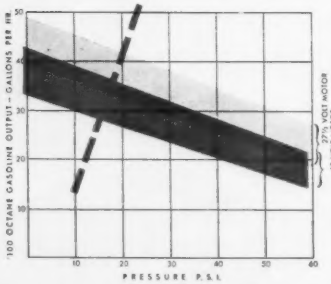

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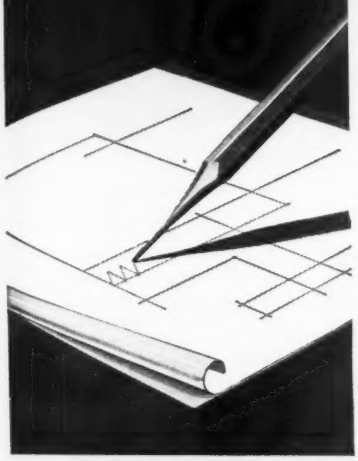

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Dickey, Myron Dwight, B.S. in Ae.E., Engineer, Electric Auto-Lite Corp.

Durham, Paul Ernest, B.Sc., Sr. Detailer, McDonnell Aircraft Corp.

Egger, Ernest Linwood, B.S. in Ae.E., Aerodynamicist, Consolidated Vultee Aircraft Corp.

Engle, Orland Jackson, B.S. (Aero.), Engineer, Tucker Corp.

Ford, John Charles, B.S. in Ae.E., Engineer, Chance Vought Aircraft Div., United Aircraft Corp.

Gard, John Alvin, B.S. in Ae.E., Asst. Stress Analyst, McDonnell Aircraft Corp.

Giles, Harry Leslie, Jr., B.S. in Ae.E., Engineer Jr. A., Boeing Airplane Co.

Harmatys, Casimir Raymond, B.S. in Ae.E., S/Sgt., U.S.M.C.R.

Harshe, Marshall Laine, B.S. in Ae.E., Jr. Engineer, Fairchild Engine & Airplane Corp.

Herb, Dona Jane, Miss, B.S. Air Transportation, Reservations Agent, Northwest Airlines, Inc.

Hernandez, Alberto, B.S. in Ae.E.

Hughes, George Robert, B.S. in Ae.E., Engineering Draftsman, Consolidated Vultee Aircraft Corp.

Humphreys, James Robert, Associate in Arts in Ae.E., Engineering Draftsman & Process Engineer, Stone & Webster Engineering Corp.

Jerome, Elwood L., B.S. in Ae.E., Mathematician "A," Douglas Aircraft Co., Inc.

Klivans, Charles Irwin, B.Sc. in M.E., Mechanical Engineer, Grade P-1, Langley Mem. Aero. Lab., N.A.C.A.

Kutsch, Howard James, B.S. in Ae.E., Research Fellow in Heat Transfer, Purdue University.

Larkby, Ralph W., B.S., Asst. Plant Engineer, Container Corp. of America.

McCamant, William Graham, B.S., Graduate Student, A. & M. College of Texas.

McDonald, Lynn Virgil, Student, Cal-Aero Technical Institute.

Merz, Ernest Joseph, Assoc. in Arts, Sr. Detailer, McDonnell Aircraft Corp.

North, Warren James, B.S., Engineering Test Pilot, Flight Propulsion Research Lab., N.A.C.A.

Pearce, Arthur Read, B.S., Graduate Student, University of Michigan.

Peck, Robert Frank, B.Ae.E., Aero. Engineer, Langley Mem. Aero. Lab., N.A.C.A.

Ryder, Earl Robert, Ae.E., Engineering Draftsman, Douglas Aircraft Co., Inc.

Sansonetti, James A.

Scholl, William August, B.S. in Ae.E.

AIR views

"Very definitely, it is not an exaggeration to state that our company believes that air freight can revolutionize merchandising."

This statement is taken from the testimony of the General Traffic Manager of a large mail-order firm given before the Civil Aeronautics Board.

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Here at Douglas we also believe in the growing future of air freight. And we are working with the air carriers and the shippers to lower air freight costs and to step up efficiency of operations.

Right now we are working on a freight version of the huge Douglas DC-6. This giant plane will, for example, carry up to 30,000 lbs. of payload. It will cut to 8 hours the flying time between New York and Los Angeles. New methods of handling and stowing cargo aboard the DC-6 also will be tested with individual air carriers.

Until the DC-6 enters service, freight versions of the Douglas DC-4 and DC-3 continue to carry the bulk of all air freight throughout the world.

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DOUGLAS AIRCRAFT COMPANY, INC.
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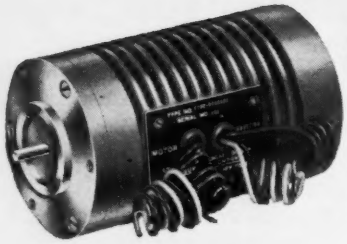
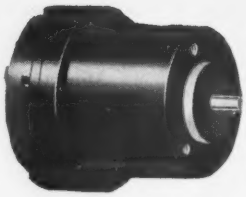
Kollsman now offers a line of special purpose AC units for servomechanisms

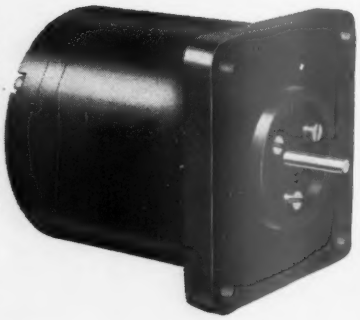


MOTOR DRIVEN INDUCTION GENERATORS — combination of a 2-phase, high-torque, low-inertia induction motor and an induction generator. Used as a fast reversing servo motor. Available with maximum stall torques of .7 (unit shown) to 6.7 (other units) oz/in.

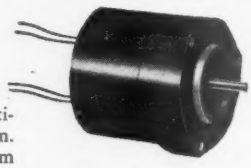


PERMANENT MAGNET GENERATORS — for applications requiring a nearly perfect AC power or potential source. Produce a sinusoidal wave form having a harmonic content under 3% in the unit shown and less than 2% in several other units.

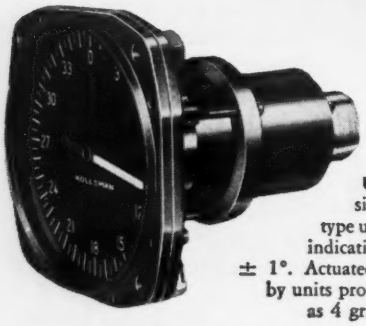
DRAG CUP MOTORS — miniature two-phase motors with extremely fast stopping, starting and reversal characteristics and high torque/inertia ratio, plus the ability to be held continuously at stall condition without overheating. Suitable for many special applications requiring torque of 1 oz/in. or less.



INDUCTION MOTORS — miniature two-phase motors with fast starting, stopping and reversing characteristics and maximum torque at zero r.p.m. Available with maximum torques of .57 (types shown) to 4.6 oz/in. (other units).



INDUCTION GENERATORS — when fed from an AC source produce a voltage output proportional to the speed of rotation of the shaft and having the same frequency as the source. Used in circuits as velocity control components.



TELETORQUE UNITS — precision built selsyn-type units for remote indication. Accurate to ± 1°. Actuated satisfactorily by units producing as little as 4 gr/cm of torque.

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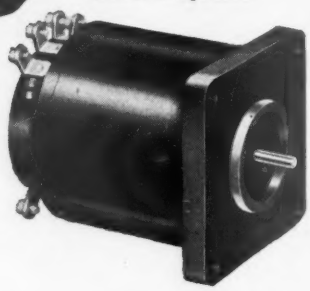

For the translation of linear or rotary motion of an actuating mechanism into an electrical impulse signal or indication, the Kollsman line of Special Purpose Motors offers the instrumentation or control engineer a wide variety of devices. Each of the units shown is representative of a comprehensive line of similar type units. They are available in many voltages and frequencies to meet various requirements.

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Further information on any or all of these units may be had upon request. Write to the Kollsman Instrument Division of Square D Company, 80-68 45th Avenue, Elmhurst, New York.

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Personnel Opportunities

This Section is for the use of individual members of the Institute seeking new connections and organizations offering employment to aeronautical specialists. Any member or organization may have requirements listed without charge by writing to the Secretary of the Institute.

WANTED

Aeronautical Engineers—Fairchild Aircraft Division, Hagerstown, Md., has vacancies in its Engineering Department at Hagerstown and also Branch Engineering Office, Washington, D.C., for engineering draftsmen, layout engineers, aerodynamicists, electrical engineers, structures and research engineers (with Ph.D. in Math. or Physics). For immediate details write Employment Manager, Fairchild Aircraft Division, Hagerstown, Md.

Jet Propulsion Engineer—Civil Service position open in Pasadena, Calif., in jet propulsion research and development field. An aeronautical engineer with strong thermodynamic and chemistry background preferred, although chemist or chemical engineer with some aeronautical engineering experience or experience with explosives could qualify. Engineering degree and 4 years' experience or equivalent necessary. Salary $5,905.20 per annum. On applying please give brief sketch of personal qualifications, education, and experience. Address: Bureau of Aeronautics Representative, 15 S. Raymond Ave., Pasadena 1, Calif.

Physicist P-5—To head applied research and experimental group in rocket ballistics. Thorough training in theoretical physics and good understanding of experimental methods essential. Must be able to guide and vigorously prosecute programs involving both theoretical and experimental studies and keep them properly related. Salary $5,904 per annum. Apply to J. T. Dale, Navy Department, Joint Board of U.S. Civil Service Examiners, 1030 E. Green St., Pasadena 1, Calif.

Physicist P-5—To head ballistics measurement and development unit. Requires experience in developing instruments for measuring physical quantities. Must be able to analyze and foresee needs for new methods of measuring ballistics quantities. Experience in radar, magnetic, photographic, and optical development desirable, though no one type is essential. Salary $5,904 per annum. Apply to J. T. Dale, Navy Department, Joint Board of U.S. Civil Service Examiners, 1030 E. Green St., Pasadena 1, Calif.

Physicist or Aeronautical Engineer P-5—To head group responsible for the operation of experimental facilities for the free-flight and wind-tunnel testing of rocket and guided missile models. Thorough knowledge of supersonic wind-tunnel techniques essential, and some acquaintance with techniques for obtaining force measurements in free flight desirable. Salary $5,904 per annum. Apply to J. T. Dale, Navy Department, Joint Board of U.S. Civil Service Examiners, 1030 E. Green St., Pasadena 1, Calif.

Physicist or Aeronautical Engineer P-5—To head applied research group in aerodynamics and stability of guided missiles. Must have a good theoretical background in supersonic aerodynamics and be capable of directing performance and stability analyses and the design of the aerodynamic envelopes of guided missiles. Salary $5,904 per annum. Apply to J. T. Dale, Navy Department, Joint Board of U.S. Civil Service Examiners, 1030 E. Green St., Pasadena 1, Calif.

Physicist or Aeronautical Engineer P-5—To head applied research group in aerodynamics and stability of rockets. Must have a good theoretical background in supersonic aerodynamics. Some knowledge and experience in rockets and ballistics desirable but not essential. Salary, $5,904 per annum. Apply to J. T. Dale, Navy Department, Joint Board of U.S. Civil Service Examiners, 1030 E. Green St., Pasadena 1, Calif.

Aerodynamicists—The University of Michigan Aeronautical Research Center at Willow Run Airport, Ypsilanti, Mich., has several openings on its research staff for aerodynamicists with experience in theoretical supersonic aerodynamics for work with supersonic missiles. Positions require good academic background and sound knowledge of dynamics and applied mathematics. Advanced degree desirable. Applicants are invited to send a complete outline of their academic qualifications and experience to the Personnel Office, University of Michigan, 208 University Hall, Ann Arbor, Mich.

Mathematician—The University of Michigan Aeronautical Research Center at Willow Run Airport, Ypsilanti, Mich., has an opening on its research staff for a mathematician with some familiarity with problems of rocket flight and analysis of trajectories. Advanced degree essential. Applicants are invited to send a complete outline of qualifications and experience to the Personnel Office, University of Michigan, 208 University Hall, Ann Arbor, Mich.

Aerodynamicists and Aeronautical Engineers—Positions available for highly qualified technical personnel with good theoretical or experimental background to engage in development of facilities and model test work in stability, control, high-speed, and supersonic aerodynamics. Projects include new models of piloted and pilotless aircraft, new wind tunnels and associated equipment, and advanced testing techniques. Salary in accordance with qualifications and Civil Service regulations. In reply, please give brief summary of personal qualifications, education, and experience. Address—Director, David Taylor Model Basin, Washington 7, D.C.

Professor—The College of Engineering, West Virginia University, has an opening for a Professor of Aeronautical Engineering and Head of Department. The salary for a properly qualified man is $6,000. Interested parties may contact R. P. Davis, Acting Dean, College of Engineering, West Virginia University, Morgantown, W.Va.

Flutter Engineer—Aeronautical Engineering graduate with several years of experience in flutter and vibration problems needed for work on advanced military aircraft. Address reply to Engineering Personnel Office, North American Aviation, Inc., Municipal Airport, Los Angeles, Calif.

Instructor—Engineer—The Test Pilot Training Division of the Naval Air Test Center, Patuxent River, Md., requires two aeronautical engineers to instruct student test pilots in aeronautical engineering fundamentals and test procedures and to act as a test-methods development group. Ratings offered Aero-Engineer (Aerodynamics) P-5 or P-6 at $5,905.20 to $7,102.20 per annum and Aero-Engineer (Power Plants) P-4 or P-5 at $4,902.00 to $5,905.20 per annum. Experience in testing, teaching, or experimental work required. Address replies to Director, Test Pilot Training Division, Naval Air Test Center, Patuxent River, Md. Civil Service Application Form 57 may be included.

895. Research Scientists—Experienced research scientists with advanced degrees and experience in applied physics, aerodynamics, thermodynamics, mathematics, or chemistry to perform supervisory research and act as permanent consulting group to engineering laboratory. Excellent opportunity for men with right qualifications. Salary $8,000–$14,000 bracket.

885. Engineer-Salesman—To head up engineering or sales, or both, of long-established company manufacturing aircraft fuel, oil, air, and water injection pumps, valves, etc. Proper man can qualify as Chief Engineer or Sales Manager. Must be experienced in design and manufacture of these products, be conversant with Air Force and Navy Requirements, be alert to sales opportunities, and have good knowledge or experience in sale of these products. Excellent prospects for profitable future. On initial application please give complete information, including former employers, duration of employment, responsibilities, name of immediate supervisor, salary, etc. Location—Middle West.

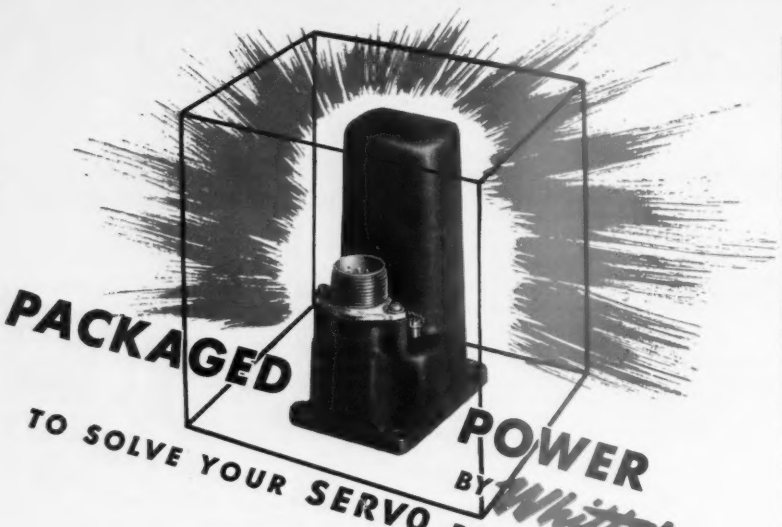
The number preceding the notices represents the Box Number of the Institute of the Aeronautical Sciences to which inquiries should be addressed.

AVAILABLE

886. Engineering Pilot—B.S. Aero. E., University of Michigan. Age 30; married. Twelve years' flying experience. Pilot—commercial airplane single- and multiengined land with instrument and flight instructor ratings; 2,300 hours' total flying time, 1,500 multiengined. Three and one-half years' flight-test experience with West Coast manufacturer as engineering test pilot. Two and one-half years' experience with air line as air-line pilot and engineering pilot. Familiar with flight analysis and C.A.A. requirements. Desires position as engineering pilot with manufacturer or air line in New York or New England area.

884. Flight-Test Aerodynamics Engineer—B.S. in Ae.E., University of Michigan, 1942. Age 27; married. Flight-test analysis or planning position desired by aerodynamics engineer with 3 years' high-speed military aircraft aerodynamics experience, including static stability performance, wing and flap design, and some wind-tunnel testing and flight-test work. Three years' pilotless aircraft aerodynamics experience, primarily in the supervision of flight-test planning, preflight calculations, and flight-test analysis and, secondly, including work on performance, wind-tunnel test analysis, stability, air loads, and special problems. Concurrently with above, 1 year's experience teaching aerodynamics in night college and 1 year's experience designing light aircraft.

883. Aeronautical Engineer—B.A.E. Cum Laude. Five years' experience in aeronautical research, including compressible flows, propeller research, wind-tunnel fan and ducted fan design. Desires position in research near or with univer-



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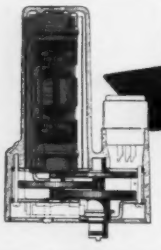

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882. Engineer—Ten years' responsible experience in production and development of electromechanical equipment. Excellent relationship with factory personnel and customers. Especially interested in costs. Age 37; engineering degree; employed at present. Prefers association with small organization.

881. Aviation Writer-Editor—Fifteen years of practical experience on newspapers, national and technical magazines, and special publications. Seeks connection with publisher or in the industry in public relations capacity. Especially good connections in the magazine field for latter assignment. Age 35; married.

880. Engineer—Brazilian; Rensselaer Polytechnic Institute graduate; speaks English fluently; resides in Rio de Janeiro. Desires to work with, or for, an American company in a technical or administrative capacity.

879. Research Aerodynamicist—Six years' experience includes teaching, Wright Field experience in performance and missile study, consulting on missile projects. At present employed in transonic research. Desires location in West Coast region with opportunity to do work on advanced degrees during next 4 years. Will consider salary in keeping with cost of living, and can be available in either Summer or Fall of 1948 by exercising option clause in present contract.

878. Aeronautics Teacher—Aviation educational consultant, high school and college levels. Author of two books on aviation education; at present teaching industrial arts aeronautics in southern high school. Desires change to college level. Specializes in lectures and demonstrations, together with practical work on such subjects as aerodynamics, structures, aircraft engines, instruments, propellers, navigation, meteorology, Link Trainer, aircraft radio, general operational aircraft methods. Designated C.A.A. aircraft and aircraft-engine examiner. Equipped with aviation teaching devices such as sound and slide films and necessary projection equipment, mock-ups, and demonstration devices of all phases, teaching devices, demonstration equipment.

877. Stress Analyst—B.Ae.E.; married. Employed by large aircraft manufacturer on West Coast for past 4 years, but now seeks location within 150 miles of New York City. In present classification for year and a half. Previous experience in structural design group and structural test.

876. Aeronautical Engineer—B.Ae., University of Detroit. Canadian citizen; age 28; married. Seven years' general experience in such phases as: design of aircraft components, shop, and ground equipment; structural analysis; plant layout; technical analysis and administration. Last 5 years as service engineer with large Canadian air line on maintenance and operational problems. Familiar with C.A.A. and British requirements. Seeks wider experience in the aeronautical or related fields. Will locate anywhere in Canada, United States, or abroad.

875. Production Liaison Engineer—B.A.E., 1941. Familiar with aircraft design, stress, research problems, and fabrication methods, factory and field. Familiar with organizational setups, systems of control for management. Broad engineering background, education, with emphasis on production and production management. Proved capable of assuming and delegating responsibility, coordinating activities of groups at various levels. Sales-minded; works well with others. Currently employed. Desires position on production staff of manufacturing organization.

874. Power Plant Engineer—Thermodynamicist—Thoroughly experienced in power-plant installation thermodynamics, reciprocating and jet engines, after-burning, cycle analysis, compres-

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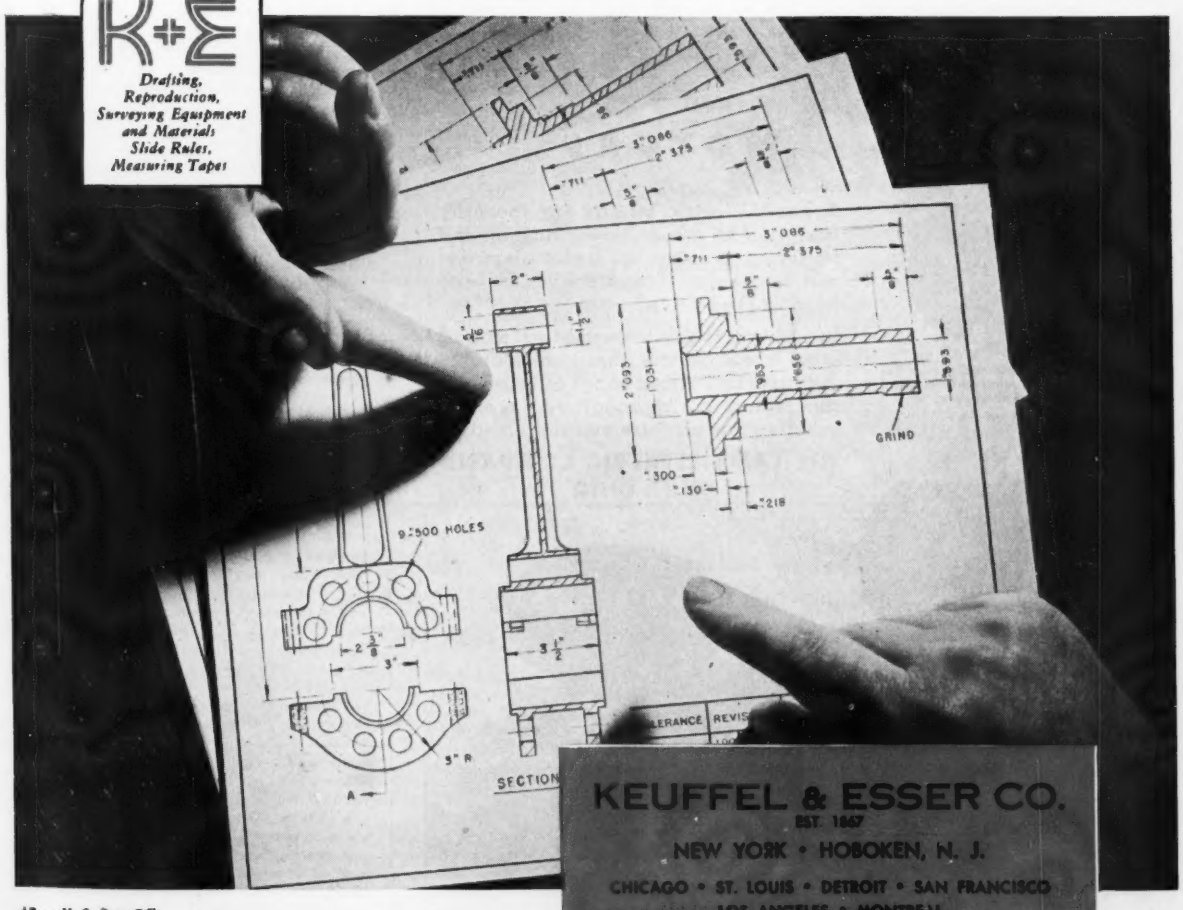

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872. Technical School Executive—Sixteen years' executive, administrative, and teaching experience in North and South America. B.S. Degree in Mechanical Engineering. Working knowledge of all phases of school operation Desires managerial position in private, Government, or company-operated technical training program. Aviation activity preferred.

871. Sales-Survey-Management Engineer—B.S. in Business and Engineering Administration, M.I.T.; 3 years' aeronautical engineering; 1½ years' engineering administration. Recent experience in aircraft export sales management including foreign contacts. Also some business survey and analysis background. Commercial pilot with civilian instructor rating; military multiengined experience. Married, age 26. Any location (including foreign) considered seriously.

870. Director of Research—Rocket motors. Experienced.

869. Engineer—B.S. in E.E., M.S. in Ae.E. Four and one-half years' experience in development, test, and manufacturing of automatic flight control systems for conventional aircraft and guided missiles. Desires position in New York City area.

868. Management or Administration—A.B. degree, University of Pennsylvania; 28 years old; single. Major in political administration, courses applicable to business administration. Courses in industrial engineering including industrial relations, business and Government, organization and organizational structure. Aeronautical engineering courses in elementary aerodynamics, performance calculation, aircraft drafting, and engineering. Over 4 years in aircraft testing in present position. Desires permanent position on junior level in management or administration with opportunity for advancement. Philadelphia, Pa.

867. Washington Representative—B.S. in Aero. Engr., married, firmly established in Washington, available for full or part-time work as technical representative. Experience with U.S. Air Force, Bureau of Aeronautics and N.A.C.A. in structures, materials, helicopters, and personal equipment. Familiar with the present research and development programs of the services on materials.

866. Layout Draftsman—Six years' experience in aircraft industry. Four years' experience on fuselage and electrical installation. Desires responsible layout position. Will locate in New Jersey or New York.

865. Structural Engineer—B.S. in M.E. Age 29; single. Eight years' experience in aircraft design with large concern. Five years in stress analysis, 2 years in static test, and 1 year in drafting. Mechanically inclined. Familiar with military and C.A.A. requirements. Will locate anywhere in U.S. Desires position utilizing experience and offering advancement.

864. Management Executive—B.S. in M.E. Over 20 years' experience in aviation, including engineering, production, quality control, contracts, contract termination, labor problems, materials, costs, and sales. Five years' research, N.A.C.A. hydrodynamics and aerodynamics. One year flight performance data analysis. A & E mechanic, private pilot. During war represented the Bureau of Aeronautics in plants of major aircraft manufacturers, heading staffs up to 160 engineering, clerical, and shop personnel. Present position: directing rocket and air engine test and development at Navy test center. Long experience in dealing with Government agencies. Desires responsible position with an organization needing a versatile, well-informed executive.

863. Research Administrator—Six years' industrial design, 8 years' chief research engineer large corporation, 3 years' professor and consultant for large engine builder, 8 years' director of university aeronautical research laboratory, 14 years' part-time teaching. One hundred and fifty patents. Specialized in power-plant, Government, and industrial contracts. Age 53. Broad experience. A-1 references.

862. Engineer—Graduate (majors in Physics and Mathematics) of University of California. One year's graduate work in Physics. Five years' experience as a stress analyst and dynamicist in aeronautical engineering. Position preferred in Los Angeles area.

860. Aeronautical Engineer and Thermodynamicist—B.Ae.E., Rensselaer Polytechnic Institute, 1940. One year's experience as junior engineer at N.A.C.A. Six and one-half years' experience with aircraft manufacturer and present employer. Four years' in aerodynamics department doing general performance work and specializing in engine cooling, cowling, ducting, heat exchange and all internal flow on aircraft for reciprocating and turbojet engines. The past 2½ years spent as head of engine research group conducting compressible flow analyses in connection with current active missile designs. Specialized in supersonic diffusers and in ram-jet engine performance. Familiar with turbojets, pulse-jets, and present-day rockets. Desires position dealing with research on ram-jets, diffusers, supersonic wind tunnels, general flow problems, or any active engine program for use on missiles. Organization or university should have a sound and stable outlook for future work in the research field. Desirable to have facilities available for continuance of education.

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Index to Advertisers

A

★Adel Precision Products Corporation 84
Aeroproducts Division, General Motors Corporation 72
Aerotec Corporation, The 68
AiResearch Manufacturing Company Division, The Garrett Corporation 2

B

BG Corporation, The ..... Inside Front Cover
★Bendix Aviation Corporation, Eclipse-Pioneer Division .. 16
Bunhill Publications, Ltd. 68

C

★Champion Spark Plug Company 64
Clifford Manufacturing Company 76
Curtiss-Wright Corporation, Wright Aeronautical Corporation Division 92

D

Doelcam Corporation 74
Douglas Aircraft Company, Inc. 85
Dow Corning Corporation 8

E

★Eaton Manufacturing Company, Saginaw Division .. Back Cover
★Eclipse-Pioneer Division, Bendix Aviation Corporation .. 16
★Thomas A. Edison, Incorporated, Instrument Division 82
★Electrol Incorporated 14
Engineering Consulting Group 83

F

Fenwal, Incorporated 62
★Foote Bros. Gear and Machine Corporation 61

G

G & O Manufacturing Company, The 80
Garrett Corporation, The, AiResearch Manufacturing Company Division 2
General Electric Company, Apparatus Department 4
General Motors Corporation, Aeroproducts Division 72
G. M. Giannini & Company, Inc. 80
★B. F. Goodrich Company, The, Aeronautical Division ... 54
Goodyear Tire & Rubber Company, Aviation Products Division 1

H

Hagan Corporation 59

I

Imperial Pencil Tracing Cloth, Keuffel & Esser Company .. 85
International Nickel Company, Inc., The 70

J

Jessall Plastics, Inc. 68

K

Keuffel & Esser Company 85, 89
★Walter Kidde & Company, Inc. 53
★Kollsman Instrument Division, Square D Company 86

L

Lamb Electric Company, The 90
Linear, Inc. 69
Lockheed Aircraft Corporation 78, 79

M

Glenn L. Martin Company, The 66

N

North American Aviation, Inc. 68

S

★Sensenich Corporation 80
★Sperry Gyroscope Company, Division of The Sperry Corporation ..... Inside Back Cover
★Square D Company, Kollsman Instrument Division 86

T

Thermix Corporation, The 68

U

United States Aviation Underwriters Incorporated 82

V

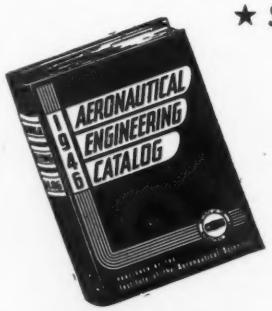
Vellumoid Company, The 68

W

Wm. R. Whittaker Company, Ltd. 88
Wright Aeronautical Corporation Division, Curtiss-Wright Corporation 92

Y

Young Radiator Company 56



★ *Specifications and further information on the aircraft products of these companies will be found in the* **1946 AERONAUTICAL ENGINEERING CATALOG**

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GOING UNDERGROUND FOR A "WHIRL"

▶ This aircraft turbine wheel is about to undergo a "whirl test"—a test to prove its ability to survive the tremendous centrifugal forces present while it spins at supersonic blade tip speeds.

▶ The test is conducted in an underground chamber from which the air is evacuated. This permits the wheel to whirl at higher speeds than required in service . . . for if the blades had to push air around at such speeds, enormous power would be required to drive the wheel. To detect any slight irregularity that might occur during the run, the test rig has an electronic indicator.

▶ Because some experimental parts are whirled to destruction to determine how much overspeed they can endure, the chamber is lined with laminated boiler plate—12 inches thick.

▶ Each newly designed turbine wheel, compressor, and supercharger impeller must prove its ruggedness in similar tests in the Wright Aeronautical research laboratories before being released for production.

▶ Another example of the painstaking research behind the development of Wright aircraft turbine and reciprocating engines.

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